RULES

Books and periodicals may be used in the Society rooms by members and friends.

Members may borrow books for home use—with the exceptions noted below—but no one shall have more than four books at any time, or keep any book more than two weeks.

Volumes belonging to a set—such as volumes of bound periodicals and of proceedings or transactions of societies—and such other books as the Board of Government may designate, may be taken from the rooms for a limited time only, by special arrangement with the attendant. They shall be subject to recall at any time.

There shall be no immediate renewal of any book on its return to the library.

A member borrowing a book shall at that time give a receipt therefor.

A fine of one cent per day per volume shall be charged for over-time, and must be paid before the delinquent can take any more books.

Hand books, indexes, current numbers or unbound files of periodicals, books belonging to the Clemens Herschel Special Library, and new books not yet placed on the regular shelves must not be taken from the rooms.

Books of unusual value are marked with a star (*), and must not be taken from the rooms, except by written permission from the Librarian, to be filed by the attendant.

Any person mutilating or losing a book shall pay for the damage, or replace the book.

Any one who violates the above rules may, upon written request from the Librarian to the Board of Government, be debarred from the privileges of the library for such time, not less than three months, as the Board of Government may determine.

(Revised June 16, 1915.)

JOURNAL

OF THE

New England Water Works

ASSOCIATION.

VOLUME X.

September, 1895, to June, 1896.

PUBLISHED BY

BOARD OF EDITORS.

Junior Editor's Office, New London, Conn.

INDEX.

INDEX.

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ERRATA.

On page 5 read John E. Burke instead of Booke.

On page 17 read Theodore H. McKenzie instead of Thomas McKenzie.

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. X. September, 1895. No. 1.

This Association, as a Body, is not responsible for the statements or opinions of any of its members.

ANNUAL MEETING.

YOUNG'S HOTEL, BOSTON, June 12th, 1895.

President Stacy presided, and the following members were present:

MEMBERS.

Everett L. Abbott, Chas. H. Baldwin, Jos. E. Beals, Dexter Brackett, C. E. Chandler, Geo. F. Chace, R. C. P. Coggeshall, Lewis P. Collins, H. W. Conant, F. W. Dean, Albert S. Glover, W. J. Goldthwait, John C. Haskell, Wm. B. Hawes, David B. Kempton, Patrick Kieran, Horace Kingman, James W. Locke, Wm. McNally, H. H. Nash, Jr., Fred. G. Perry, Geo. S. Rice, W. H. Richards, Geo. J. Ries, J. Herbert Shedd, Geo. A Stacy, Lucian A. Taylor, Robert J. Thomas, J. Alfred Welch, J. C. Whitney, W. P. Whittemore, E. T. Wiswall, Geo. E. Winslow, W. G. Zick.

The following companies were represented:

Thomson Meter Company, National Meter Company, Hersey Manufacturing Company, Neptune Meter Company, R. D. Wood & Company, Deane Steam Pump Company, Holyoke Hydrant & Iron Works.

The Secretary presented the following applications for membership, which had been endorsed by the Executive Committee:

RESIDENT ACTIVE.

Herman Gregg, Civil Engineer, Waltham, Mass.
Frank W. Hodgdon, Water Commissioner, Arlington, Mass.
Morris Knowles, Civil Engineer, Lawrence, Mass.
Walter W. Patch, Civil Engineer, Boston, Mass.
Sidney Smith, City Engineer, Rutland, Vt.
W. J. Sands, Mechanical Engineer, Boston, Mass.

NON-RESIDENT - ACTIVE.

G. S. Williams, Engineer Water Department, Detroit, Mich.

The Secretary was instructed to cast the ballot of the association in favor of the applicants, and they were declared elected.

The President then announced the following as a committee to nominate officers for the ensuing year: John C. Haskell, Albert F. Noyes, Patrick Kieran, H. G. Holden, Freeman C. Coffin.

On Motion of Mr. Coggeshall it was voted, that when the meeting adjourned it be to meet at Burlington, Vt., Sept. 11, 1895.

Adjourned.

The members and guests, including ladies, then took a carriage drive through the Boston Park System and Arnold Arboretum, and also visited the Chestnut Hill Pumping Station, to see the new high duty Leavitt pump. The trip, which was arranged by Mr. Dexter Brackett, was thoroughly enjoyable.

PROCEEDINGS OF THE FOURTEENTH ANNUAL CONVENTION.

BURLINGTON, VT., September 11, 12 and 13, 1895.

The meetings of the Convention which were held in the hall of the Young Men's Christian Association on the morning, afternoon and evening of September 11th, evening of September 12th, and morning and evening of September 13th were well attended.

MORNING SESSION.

WEDNESDAY, September 11, 1895.

The Convention was called to order by President Stacy.

On motion of Mr. Coggeshall, the reading of the minutes of the last meeting was dispensed with.

The President introduced His Excellency, Governor Woodbury, of Vermont, who spoke as follows:

ADDRESS OF WELCOME BY GOVERNOR WOODBURY.

Mr. President and Gentlemen of the New England Water Works Association:

It was the expectation and desire that His Honor, Mayor Van Patten, should welcome you to the city of Burlington. It is my pleasant, although unexpected privilege of appearing as a substitute in his place, to welcome you to the Queen City of Vermont; and I also may say that I voice the sentiment of the people of the State of Vermont, if in my official capacity I welcome you to Vermont, and I do so most heartily. I do not know that the cordiality of our invitation to you to come to Burlington would have been so intense if we had supposed that you would have brought so much water with you at one time, as descended upon us this morning. But owing to our ample sewers and the conformation of the ground, the water has passed off into the lake, ere this, so that this afternoon, if the rain does not continue, you can walk about Burlington dry shod.

I think it is very fitting that you should come to Vermont, especially to the shores of this beautiful sheet of water, Lake Champlain, because you know Vermont believes in water, and does not believe in much of anything else. The fact is that we do not allow anything to be sold here except plain water, and perhaps soda water, or something of that kind, ginger ale, etc., so it is peculiarly appropriate that men who represent the branch of industry you do should come to this State that you may talk about the beverage which Vermonters almost exclusively deal in and use.

You represent an industry which is of vital importance to the human race, that of water, and of pure water. And it is through these meetings, I judge, although I am not familiar with them, and the discussions which arise in them, that the water supplies are constantly improving in the New England States. These discussions cannot fail of being of great benefit to the people whom you supply. In our own case here, in Burlington, the discussions which, perhaps, started in your Association, but were taken up actively by our own people, have resulted in our obtaining within the last two years an ample supply of what we believe to be as pure water as is found in New England.

I know that you do not care to listen to a speech this morning. and I will not inflict one upon you. I can assure you that we ap-

preciate the selection of Burlington for the holding of this Convention, and we sincerely hope that your stay with us, and that of your wives and daughters and invited guests, may be a pleasant one, and we trust that the elements will be propitious on the morrow, so that you may enjoy a sail upon our beautiful lake and your visit to that wonderful work of nature, Ausable chasm; and that when you leave Burlington you will be glad you have been here, as I am sure we shall be. Wishing you a pleasant and profitable time, I will now give way that you may proceed to the regular business of the convention. (Applause.)

RESPONSE BY PRESIDENT STACY.

Your Excellency: Previous to this meeting, The New England Water Works Association has held its conventions in every State in New England with the exception of Vermont. For a long while the eyes of the directing force of the Association have been turned toward this State as a desirable place in which to hold our meetings where we could gain inspiration for our work, to make us better fitted for the labors before us. And last year it was a unanimous and hearty vote and expression of opinion that we should hold our next convention in Vermont. And as long as we had delayed for so many years before visiting the State, we were determined to visit the very heart of it, and we selected Burlington as our objective point; and the reception we have received shows that we did not make a mistake. Allow me to thank you in behalf of the New England Water Works Association, for your hearty and cordial welcome, and permit me to extend to you, and to the City Government and to the citizens of Burlington, and of Vermont, a cordial invitation to attend any and all of our meetings.

The Convention then proceeded to the regular order of business.

ELECTION OF NEW MEMBERS.

The Secretary presented the following list of applicants for membership, with the approval and recommendation of the Executive Committee:

RESIDENT ACTIVE.

H. M. McIntosh, City Engineer, Burlington, Vt.; Alex. S. Dawson, Civil Engineer, Boston, Mass.; H. L. Colby, Civil Engineer, Salem, Mass.; Forrest E. Bisbee, Superintendent, Auburn, Me.; D. H. Gilderson, Superintendent, Bradford, Mass.; Richard J. Flynn, Engineer, Brookline, Mass.; Orrin B. Bates, Superintendent, Clinton, Mass; Jas. F. Bigelow, City Engineer, Marlboro, Mass.; Chas. F. Murphy, Water Inspector, Marlboro, Mass.; L. C. Greene, Water Commissioner, St. Albans, Vt.

NON-RESIDENT ACTIVE.

Daniel B. McCarthy, Superintendent Water Works, Waterford, N. Y.; Henry Henry E. Eastman, Superintendent Water Works, Westport, N. Y.; M. L. McDonald, Jr., Superintendent Water Works, Santa Rosa, Cal.; Warren R. Kinsey, Civil Engineer, Newark, N. J.; John H. Myers, Jr., Civil Engineer, Brooklyn, N. Y.; Wm. Clayton, Superintendent, Newtown, N. Y.; J. B. Fish, Superintendent, Scranton, Pa.; Jas. E. Booke, Princeton, N. J.; Chas. E. Eddy, President Water Company, Plattesmouth, Neb.

ASSOCIATE.

The Goulds Manufacturing Company, Seneca Falls, N. Y.; H. Mueller Manufacturing Company, Decatur, Ill.

On motion of Mr. Noyes, the Secretary was directed to cast the ballot of the Association for the applicants, which he did, and they were declared elected to membership.

ADDRESS OF PRESIDENT STACY.

Gentlemen of the New England Water Works Association: We have assembled to-day in this pleasant city to take up the business of our Fourteenth Annual Convention which was called in Boston last June and adjourned to this time and place, for reasons that are probably well known to you all.*

The records of the past year show that we are stronger, both numerically and financially, than we were at the beginning of the year. This, I can say, has been the record of every year since that comparatively small but enthusiastic body of water works men, twenty-seven in number, in June, 1883, organized and brought into being the New England Water Works Association; truly they builded better than they knew, for it is safe to say that, not one of the founders of this organization could possibly have foreseen that it would expand and grow to its present proportions. To-day it stands without a peer, and so broad has been its platform, and so wise and harmonious has been its management, that it has attracted

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*As mentioned in the June number of the *Journal*, page 200, it was the original plan to hold the convention in Burlington in June, 1895. But after this arrangement had been made, it was announced that the annual convention of the American Society of Civil Engineers was to be held in Boston on the dates selected, and as many of our members were desirous of attending that convention, and as for other reasons it was impracticable to hold the convention at any other time in June, it was decided to call the convention in Boston on the date required by the constitution, and then to adjourn without transacting business, to Burlington, in the second week of September.

to its ranks men of every station, from the humblest superintendent to the scientist and engineer of world-wide reputation. Our membership, June 1st, 1895, was 401 active, 81 associate, and five honorary members; a total of 487, a gain of 44—one of the largest in the history of the organization. Out of this large membership, for the year ending June 1st, 1895, death had removed but two of our members: Phineas Ball died Dec. 19th, 1894. He joined this association June 10th, 1886, and was a constant attendant at our gatherings, when health and business permitted. His genial countenance, pleasant smile, and wise counsel, will be much missed at our meetings. Lincoln C. Haywood, died Jan. 15th, 1895. He had been a member but six days. Since the date of our Annual Meeting, June 1, two more of our active members have been removed from our ranks by the hand of death. John L. Harrington, the successor of the late Hiram Nevons, Superintendent at Cambridge, died Aug. 10th, 1895. He joined the association in June, 1887, and was a member of the Finance Committee, and active in promoting the interests of the association. Marshall M. Tidd, died Aug. 20th, 1895. He was an eminent hydraulic engineer, and an active participant in our meetings, a genial companion and a firm friend, and did much to make our meetings interesting and instructive.

We have had five meetings since our annual convention in June, 1894. The first was our fall field day, Sept. 22d, when fifty-two of our members, and their ladies and friends, took a special car for the Crawford House, where we arrived in the afternoon. From this time on, walks and drives among the grand and beautiful scenery for which that place is noted, occupied the time until the morning of the 24th, when we started for home, a tired but happy party. The weather was perfect, and nothing occurred to mar the pleasure of the trip, and we are indebted to Mr. Dexter Brackett for his untiring efforts in our behalf and for a large share of the pleasures we enjoyed. Meetings have been held at Young's Hotel in December, January, February and March, all of which were well attended.

The papers presented at these meetings, and the discussions following them, have been instructive and much enjoyed, and it is impossible for one connected with water works enterprises to attend the meetings of this association without becoming better fitted to

cope with the difficulties that are sure to come to him in his business, and I believe that every city and town should oblige the managers of its water works to attend the meetings of this association; certainly no man who is worthy of his position can do so without becoming more valuable to his employers, and if they made it a part of his duty to attend, and paid his expenses, it would yield a better return than any other investment they could make.

The *Journal*, published quarterly by the association, is a valuable addition to any water works library. Its numbers contain a fund of theoretical and practical knowledge in regard to every detail, from the largest to the smallest, of water works construction and management. We certainly owe a debt of gratitude to its founders, and to the editors who have so ably managed it.

The question of permanent headquarters has been before the association for some time, but no opportunity to secure them, within the means of the association, has presented itself until recently. A number of meetings have been held during the past summer by the executive committee, and the committee appointed at Hartford, in relation to the matter, a detailed report of which will be made during this convention. I believe that if permanent headquarters can be secured within the means of the association, without increasing the tax on the members, that it will be of great benefit to the association as a whole.

As the demand for water grows greater and greater, the problems we are called upon to solve, grow in magnitude and number. The supply, its quality, and its protection from pollution, the prevention of waste, are live questions that require our best thought and study. We are all agreed that the supply should be wholesome and abundant, to be used freely for all necessary purposes, but waste of water is like waste by fire; a total loss to the people who are taxed to maintain the works. There is, naturally, a difference of opinion as to the best way to reach the desired results, and a free and full discussion of these and kindred subjects, as they come before us from time to time, will materially assist us in solving these problems. Let no one hesitate to give to the association his experience, no matter how small, in the management of his business, whether it is a success or not, for we often learn more valuable lessons from our failures than we do from our successes, and small things are, in the aggregate, a large factor in the progress of events in our every day lives.

I wish to thank you all for the honor you have conferred on me in electing me to the presidency, and for your courtesy and hearty co-operation; what measure of success the association has attained the past year is due more to your work than it is to mine; to your quick response to every call and your unflagging interest and support of the officers of this association.

Every member regretted the necessity that caused the resignation of our former Secretary, but we have the pleasure of knowing that while he was obliged to resign the office he had so long and ably filled, we retain as a member one who has done so much to make the association what it is. We are indeed fortunate in securing so able a man as our present Secretary to fill the vacancy; he has been untiring in his efforts in behalf of the association.

And now as we turn our faces to the future, let us not forget the duty we owe to ourselves and to the association; let us do our part in making all the meetings of this convention profitable and interesting; and in the year to come let us encourage our officers by our presence and work, remembering that in a large measure the continued success of the association rests with us; so that my successor may have the pleasure of saying, at the next annual convention, as I have the pleasure of saying now, our association is stronger, larger, and more powerful for good than it ever was before.

The Treasurer then submitted his annual report as follows:

ANNUAL REPORT OF THE TREASURER.

George E. Batchelder, in Account With the New England Water Works Association.

1894.		Dr. To Amount Received.	
June 15.	Received from	Cambridge National Bank	$ 79 56
"	"	" Savings Bank	28 48
"	"	Cambridgeport Savings Bank	1,190 36
July 15.	"	R. C. P. Coggeshall	665 05
Oct. 22.	"	"	2,000 00
1895.			
Jan. 22.	"	"	1,017 75
Feb. 15.	"	Dexter Brackett, Secretary pro tem	258 25
June 5.	"	J. C. Whitney, Secretary	475 85
1895.		Accrued Interest In	
Aug. 1.	Mechanics Savings Bank		19 76
" 1.	People's Savings Bank		32 16
Sept. 1.	City National Bank		21 80
			$ 5,789 02

1894.		Cr. By Payment To	
July	3.	Bacon & Burpee	75 00
"	3.	Harold L. Bond	6 00
"	3.	Thomas P. Taylor	20 75
"	3.	Walker, Young & Co	6 25
"	12.	Boston & Albany Railroad Co	30 00
"	12.	James B. Fuller & Co	14 00
"	12.	W. N. Hughes	33 00
"	12.	E. D. Leavitt	26 25
"	19.	Tilly Haynes	112 00
Aug.	4.	Hattie F. Milligan	20 00
Sep.	14.	Electro-Light Engraving Co	10 42
"	14.	F. T. V. Groll	5 25
Oct.	8.	Robert Burlen	17 15
"	8.	W. N. Hughes	5 50
"	8.	Putnam, Davis & Co	12 00
"	8.	W. H. Richards	97 18
"	8.	Engineering News Publishing Co	1 85
"	8.	The Heliotype Printing Co	13 50
"	22.	The Day Publishing Co	201 40
Dec.	4.	A. L. Ward	10 00
"	13.	R. C. P. Coggeshall	398 34
"	17.	Young's Hotel	20 00
"	18.	George A. Stacy	14 00
"	20.	Mercury Publishing Co	201 39
1895.			
Jan.	5.	W. H. Richards	89 74
"	5.	The Day Publishing Co	256 17
"	12.	Young's Hotel	10 00
"	31.	The Heliotype Printing Co	16 00
Feb.	12.	Walter T. Almy	28 32
"	19.	Young's Hotel	10 00
Mar.	14.	Dexter Brackett	41 67
"	14.	R. C. P. Coggeshall	110 53
"	14.	Electro-Light Engraving Co	1 08
"	15.	Young's Hotel	10 00
"	21.	Hub Engraving Co	55 80
"	22.	"	1 94
Apr.	2.	Bacon & Burpee	59 50
"	12.	W. H. Richards	100 71
"	12.	The Day Publishing Co	233 95
"	12.	Lettice R. Washburn	13 99
May	13.	Hub Engraving Co	10 89
June	13.	Mercury Publishing Co	108 20
"	21.	J. C. Whitney	181 61
July	12.	W. H. Richards	93 33
"	17	The Day Publishing Co	331 33
			$ 3,115 99

BALANCE ON HAND.

People's Savings Bank	$ 1,032 16
City National Bank	440 87
Safe Deposit and Trust Co	1,200 00
	$ 2,673 03

Respectfully submitted,

GEO. E. BATCHELDER, *Treasurer.*

We hereby certify that we have examined the above account and approve it as correct.

A. R. HATHAWAY,
FRANK A. ANDREWS, } *Finance Committee.*

On motion of Mr. Coggeshall, it was voted to receive and accept the report, and that it be placed on file and spread upon the records.

The Secretary submitted the following as his report:

REPORT OF THE SECRETARY.

Summary of Statistics Relative to Membership for Year Ending June 1, '95.

ACTIVE MEMBERS.

June 1, 1894, total active membership		365	
Withdrawals during year		10	
		355	
INITIATIONS:			
June, 1894	24		
December, 1894	7		
January, 1895	3		
February, 1895	8		
March, 1895	4		
	—	46	
June 1, 1895, total active membership			401

HONORARY MEMBERS.

June 1, 1894, total honorary membership		5	
June 1, 1895, total honorary membership		—	5

ASSOCIATE MEMBERS.

June 1, 1894, total associate membership		73	
Withdrawals during year		2	
		71	
INITIATIONS:			
June, 1894	8		
December, 1894	2		
	—	10	
June 1, 1895, total associate membership			81
June 1, 1895, total membership			487

A gain for the year of 44.

Summary of Receipts for Year Ending June 1, 1895.

DR.

Balance from old account		$ 665.05
Received for advertisements		1,695.00
"	initiation	307.00
"	dues	1,489.00
"	Journals	240.00
"	badges	21.85
"	electrotype	1.00
		$4,418.90

CR.

June 20.	Paid Geo. E. Batchelder, Treas.	$ 665.05
Oct. 20.	" "	2,000.00
1895.		
Jan. 19.	Paid Geo. E. Batchelder, Treas.	1,017.75
Feb. 13.	" "	260.25
June 1.	" "	475.85
		$4,418.90

On motion of Mr. Richards, it was voted that the report be received and placed on file, and that a copy be spread upon the records.

PERMANENT HEADQUARTERS.

The President called upon Secretary Whitney for a report on behalf of the Executive Committee on the subject of permanent headquarters for the association.

THE SECRETARY. The association has had under consideration for the last five years the subject of permanent headquarters. Up to the present year the financial conditions have been such that it seemed hardly advisable to take any decisive steps; but during the present year the Boston Society of Civil Engineers, which has been considering the same subject of permanent headquarters, has secured an option upon some desirable rooms in the new Tremont Temple building in Boston, and has wished to have some other society join with them in occupying the rooms and in meeting the expenses. The rooms which they wish to secure will cost about $1,400 or $1,500 a year. The Boston Society, which is now occupying quarters which are not adequate for its needs, has an arrangement with a dealer in supplies to occupy desk room, and take care of the rooms and share the expense. This arrangement the Boston Society wished to continue with the same concern in their new lo-

cation, and this concern has agreed to contribute towards the expense $500, to furnish a telephone free of charge, and to look after the rooms, to keep the books arranged in order, etc. This $500 reduces the expense to be met by both associations to $1,000. The Executive Committee of the New England Water Works Association made an offer to the Boston Society of Civil Engineers agreeing to pay $400 of that amount, this sum of $400 to include all expenses, the rent of the rooms, light and heat and care; so that the total expense to the Water Works Association was not in any case to exceed $400. The offer was made for a term not exceeding three years. It was also agreed that neither society should allow a third society to use the rooms in any way without the consent of the other society, so that no third society should be allowed there without unanimous consent. That offer the Boston Society still have under consideration. The President of the Boston Society of Civil Engineers, Mr Albert F. Noyes, is a member of the New England Water Works Association, and is now with us, and if there is anything to be added in regard to the position of the Boston Society in the matter, he can explain it.

Mr. Noyes. I do not know that there is anything to add to the report that the Secretary has made, except this: He has stated that the committee of the Boston Society, having the matter in charge, had obtained an option on certain rooms, and that is true; but when they came to examine the rooms they found that they were not as large as they were shown on the plan which had been submitted to them. So a proposition was made to the Executive Committee of the Tremont Temple building for rooms which would give an area equivalent to that for which we had previously negotiated, and the committee still have that under advisement.

The rooms for which we are negotiating are about 18 feet wide by 56 feet long; there will be a small section taken out for an office, leaving a space something like 18 feet by 45 or 50 for the libraries of the two associations. It has been assumed that one section would be set apart for the library of the New England Water Works Association, and another section for the library of the Boston Society of Civil Engineers, with free access to both libraries for the purpose of reference, to the members of both societies.

There is a large hall adjoining the rooms, and a proposition has also been made for renting that hall for the regular meetings of

the Boston society, and undoubtedly similar arrangements could be made for any meetings of the association which might be held in the city of Boston.

It was also thought by the members of the New England Water Works Association who had given the matter considerable attention, that one of the functions of this society should be to accumulate a library of water works reports. I believe the Secretary now has in his possession a large number of reports from various cities, and it is desirable to have full and complete sets. It was thought that if permanent headquarters were obtained (and I am now speaking as a member of this association, and as one who has a strong interest in its success and welfare), we might have such a library, with a full and complete file of reports of all water works, as well as a collection of standard books on water works subjects, to which our members could have easy access at all times.

I might add that it was felt that the general nature of the work of the two associations was so similar that they could use the rooms jointly with advantage.

The President. I don't want to take up too much time on this subject, but I consider it of vital importance, and it is something which ought to be put into such shape that it can be handled by your committee promptly and easily when the opportunity arrives in the negotiations with the Boston Society. Your Executive Committee assumed a certain amount of power which, perhaps, did not really belong to them, believing that this was a good time to secure headquarters, and that it was necessary to act promptly. After looking the ground all over we felt safe in making the offer we did to the Boston Society, trusting that you would approve our action. It should be clearly understood that the Boston Society were to lease the rooms, and sublet them to us, and we only agreed to take them for three years. That would call for an expenditure of $1,200 in the three years for rent.

We found we had something over $2,500 on hand at that time (it is about $2,600 now), and that the surplus of the present year is nearly $700. So we felt we would not be doing our duty to the association if we did not embrace this opportunity as it presented itself to secure headquarters for the association; for if, at the end of three years it should be found undesirable to continue the arrangement, we should have been amply repaid for our expendi-

ture by the experience we should have gained, and by the benefit we should surely have derived from the use of the rooms during that period, even if we did not want to continue the arrangement further. But as Mr. Noyes has said, the negotiations have not been carried on as rapidly as was expected, and no final action has been taken, and the association itself now has the opportunity to take action to authorize their committee to act for them in the matter, if they care to go on with it any further. Our position has been clearly stated to you, and we, believing that we acted for the best interests of the association, expected to come before you to-day asking you to endorse our action; but as the matter has not yet gone through, we now ask you, if you see fit, to authorize somebody to carry on the negotiations, so that the association, as a whole, will be responsible for them.

Mr. Coggeshall. There is one thought which has occurred to me which I will suggest for the benefit of our members. I take it for granted that the committee will make such provision that any member who happens to be in Boston can have access to these rooms during the daytime; and if there is any special matter in connection with water works subjects, on which he wishes information, he can consult the books in the library at any time.

Mr. Noyes. Mr. President, perhaps I may be able to answer Mr. Coggeshall's question. Some three or four years ago this question of permanent headquarters was before the Boston Society of Civil Engineers. It was beyond their means, without increasing the dues beyond what was thought prudent, to obtain permanent headquarters, with a person in the employ of the society, in charge of the rooms. At that time one of the members of the association came forward and offered to pay part of the rental, to look after the library, to furnish a telephone, which the members could use as they needed, and also to keep the rooms open during the daytime. That arrangement has been carried out in a very satisfactory manner, and it has been a great success. It has been found desirable, however, to have larger quarters, so as to extend the usefulness of the society, and it has been suggested for some years that some similar arrangement might be made between the Boston Society and the New England Water Works Association with a third party, whereby suitable permanent headquarters might be obtained for both societies.

Now I do not consider that it would be within the means of either association, or of both of them, to employ a person to look after the libraries, and to keep the rooms open, which is certainly desirable, and I have no reason to doubt that the arrangement now proposed can be carried out in the same satisfactory manner as it has been done with the Boston Society alone during the last three or four years. The rooms can be used as a place for meeting by members of the association, the libraries would always be open for reference, and the members of this association would have access to the library of the Boston Society of Civil Engineers, which is quite extensive, and contains many books on scientific subjects in which members of this association are interested. The elevator will be run up to ten o'clock at night, and members who desire to visit the library in the evening can, undoubtedly, have keys. That has been the custom with the Boston Society, keys being furnished by the Secretary at cost. In that way access can be had in the evening, although otherwise the rooms are only open in the daytime.

THE PRESIDENT. Well, gentlemen, I hope you will express your minds freely in regard to this subject. Perhaps you may want to talk it over among yourselves a little, not having had a chance to do so, as much as you would like, and, therefore, with your permission, we will postpone the consideration of the matter for the present, and I will call it up at some later time during the convention. In the meantime, you can be thinking it over.

The President then called upon Mr. Crandall, Superintendent, Burlington, Vt., to read a paper on "The Water System of Burlington, Vermont." The paper was discussed by Messrs. Noyes, Williams, Gilbert, Fish and Hazen.

Prof. Storrs, of the University of Vermont, then read a paper on "Electrolysis." This was discussed by Messrs. Winslow, Gilbert, Fish, Chase, Haskell, Williams, Milne and Crandall.

AFTERNOON SESSION.

The Convention met promptly at 2.30 P. M.

Mr. John C. Haskell, Superintendent, Lynn, Mass., read a paper on "The Water Supply of Lynn."

John Thompson, Civil Engineer, New York, followed with a paper entitled, "Uniformity of methods in the bench-testing of

water meters, also comprising a few suggestions as to apparatus therefor, with tables of deliveries through small orifices of specified form under definite pressure.'' An interesting discussion followed the reading of the paper, participated in by Messrs. Haskell, Richards, McNally, Holden, Williams, Gilbert, Winthrop, Chase, Lockwood, Noyes, Hayes, the President and others.

EVENING SESSION.

At the evening session, at which there was a large attendance of members and ladies, and also of citizens of Burlington, Superintendent Crandall explained numerous stereopticon views of features of the Burlington water system. He was followed by Prof. Sedgwick of the Massachusetts Institute of Technology, who made an address, illustrated by the stereopticon, on ''The Sanitary Condition of the Burlington Water Supply.''

EVENING SESSION.

THURSDAY, September 12th.

Desmond FitzGerald, Superintendent of the Western Division Boston Water Works, gave ''A Brief Description of the St. Louis Water Works,'' illustrated by the stereopticon.

The Secretary read a paper submitted by Clements Herschel, entitled, ''Advisability of having tests of water meters, and of other articles of commerce, conducted by the association.'' The paper was discussed by Messrs. Cook, Noyes, Whitney, Thomas, Haskell, Smith, Richards and Prof. Swain.

MORNING SESSION.

FRIDAY, September 13th.

The first business was the election of officers. Mr. Haskell, for the Nominating Committee, made the following report:

Mr. President and Fellow Members: The committee appointed to nominate officers for the New England Water Works Association, for the ensuing year 1895–1896, have attended to their duty, and I now submit the names of the parties selected by them for your consideration.

PRESIDENT.

DESMOND FITZGERALD, Superintendent Western Division and Resident Engineer, Additional Supply, Boston Water Works, Brookline, Mass.

VICE PRESIDENTS.

H. T. SPARKS, Superintendent Water Department, Public Works Company, Bangor, Me.; CHARLES K. WALKER, Superintendent, Manchester, N. H.; F. H. CRANDALL, Superintendent and Treasurer, Burlington, Vt.; JOSEPH E. BEALS, Superintendent, Middleboro, Mass.; THOMAS MCKENZIE, Engineer, State Board of Health, Southington, Conn.; WILLARD KENT, Civil Engineer, Woonsocket, R. I.

SECRETARY.

J. C. WHITNEY, Water Registrar, West Newton, Mass.

TREASURER.

GEORGE E. BATCHELDER, Registrar, Worcester, Mass.

SENIOR EDITOR.

ALLEN HAZEN, Civil Engineer, Boston, Mass.

JUNIOR EDITOR.

WALTER H. RICHARDS, Civil Engineer, New London, Conn.

EXECUTIVE COMMITTEE.

JOHN C. HASKELL, Superintendent, Lynn, Mass.
HORACE G. HOLDEN, Superintendent, Nashua, N. H.
R. C. P. COGGESHALL, Superintendent, New Bedford, Mass.

FINANCE COMMITTEE.

A. R. HATHAWAY, Registrar, Springfield, Mass.
ARTHUR W. F. BROWN, Registrar, Fitchburg, Mass.
WILLIAM MCNALLY, Registrar, Marlboro, Mass.

Respectfully submitted for the committee:

JOHN C. HASKELL, *Chairman*.
HORACE G. HOLDEN,
FREEMAN C. COFFIN,
PATRICK KIERAN,
ALBERT F. NOYES.

On motion of Mr. Forbes, the Secretary was instructed to cast one ballot as the ballot of the association for the nominees recommended by the committee, and they were declared elected officers for the ensuing year.

MEMBERS ELECTED.

The Secretary read the following names of applicants for membership, duly approved and recommended by the Executive Committee.

RESIDENT ACTIVE.

James W. Graham, Supt. Meter Department, Portland Water Company, Portland, Maine; Henry Chandler, Manchester Water Board, Manchester, N. H.; J. M. Davis, Supt. Water Works, Rutland, Vt.; Joel Foster, Supt., Montpelier, Vt.; Fred B. Gleason, Foreman Water Department, Marlborough, Mass.

NON-RESIDENT ACTIVE.

Lemuel Amerman, Supt., Scranton, Pa.; W. F. P. Sealy, Potsdam Water Works, Potsdam, N. Y.

ASSOCIATE.

Massachusetts Chemical Company, South Boston.

On motion of Mr. Coggeshall, the Secretary was directed to cast the ballot of the association for the above named candidates for membership, and they were declared elected.

Charles K. Walker, Superintendent, Manchester, N. H., then read a paper entitled "A Short History of the Manchester High Service."

PLACE FOR NEXT ANNUAL CONVENTION.

Mr. Walker of Manchester extended a cordial invitation to the association to visit Manchester next year, or the year after, or at any time.

Mr. Noyes. Mr. President, as this is a question which needs some little consideration, I would move that the selection of a place for the next annual convention be left in the hands of the Executive Committee, with full powers.

Adopted.

PERMANENT HEADQUARTERS.

The President. As I said at the first session of this convention, there is a question pending with regard to headquarters for the association, and something definite ought to be done about it. I therefore wait any motion or action that the Convention sees fit to take in the matter.

Mr. Coggeshall. I move that the Chair give full liberty to any of the associate members present to enter into this discussion, as we would like to have their views upon this subject, and to hear the question presented from their standpoint.

Adopted.

The President. I await any motion in regard to the subject of permanent headquarters for this association.

Mr. Forbes. I am personally in favor of securing permanent headquarters, but I think that there are many who would not wish to do so unless it could be done without increasing the annual dues. It would seem to me that the better way would be to leave the whole matter to the Executive Committee, with full powers, but with this suggestion: that no action be taken towards securing permanent headquarters unless it can be done without increasing the annual dues, and I move that the whole matter be referred to the Executive Committee, with full powers, with the exception that no expense be created which cannot be met by the annual dues as now paid by the members.

The President. Do you wish to limit them as to time?

Mr. Forbes. No; I would give them unlimited time and powers, with the exception of not increasing the dues of the members.

The motion was seconded by Mr. Williams.

The President. I would say that as far as our negotiations were carried, the arrangements proposed could be made without increasing the dues, or embarrassing us at all in our finances.

Mr. Codd. Permanent headquarters would, of course, benefit more directly those members who are in the habit of going to Boston frequently, but I should not object to carrying out the scheme proposed, at almost any cost, even if it increased our dues. There is nothing for which we pay two dollars from which we get so much return as we do from this association.

The President. Is there anything to be said by any member on this motion?

Mr. Gilbert. I fear that perhaps this matter is not thoroughly understood by everyone so that they can vote intelligently upon it. Leaving this matter with the Executive Committee, with full powers, might be leaving it in a way that will result in some feeling among members of the association, and I suggest that it might be well to have the matter once more fully explained before we vote.

The President. I would say that all negotiations up to this point have been conducted by the Executive Committee which will go out of existence to-day. The matter came up at a time when it was impossible for us, without considerable expense and inconvenience, to call a special meeting of the association. The Boston Society of Civil Engineers have a room which they occupy at the present time, which room they have found too small for them. An associate member of our association has desk room there, and his stenographer has charge of the library, and keeps the room in order, and keeps it open to members of the Boston Society during the day; and with that arrangement the Boston Society was able to meet the expense of having headquarters. It was, at first, an experiment with them, as it is with us to-day. The experiment has been so satisfactory that they are looking now for increased accommodations. In looking over the matter they found that adequate accommodations for all of their requirements would involve expenses greater than they could well pay, although their dues are more than double ours, and they will probably be still further raised. Now, they thought that if they could get the New England Water Works Association to go in with them or sublet from them a part of the room they might secure, they would then have quarters which would be better adapted to the requirements of their evening meetings. The blue print plan of the new Tremont Temple building in Boston showed three rooms which could be thrown together, and they proposed to make an arrangement with the party they have had in their present quarters, to take charge of the rooms and to pay a part of the rent, the same as formerly, except that the party taking charge of them will be in a room entirely separate from the other rooms of the society, but with a door between the office of the firm and rooms of the society. They cannot afford quarters which would be adequate for their purposes without making some such arrangement, and if the Water Works Association withdraws the proposition now pending, and do not make any arrangements with them, the Boston Society still proposes to have new quarters, although they will have to be smaller than those which have been contemplated. They proposed to the New England Water Works Association, that we, being a kindred organization, closely allied in our work with them, should sublet from them the right to use a part of the space exclusively for our library, for which we ought to

have had some accommodation years ago, for we could easily accumulate a valuable library if we had a place where we could keep our books, and file away our documents. A part of the wall space would be set aside exclusively for our library, but the whole room would be used in common by the two societies.

The proposition we made to the Boston society was that we would pay $400 a year, they leasing the property and subletting it to us. That was to be the whole expense to us, including light, heat, and janitor service, and the offer was for three years only. And it was also provided that no other society should occupy the premises without the consent of both organizations.

Since then, owing to some misunderstanding in regard to the exact sizes of the rooms, the negotiations have been delayed and are still pending. Now, the Executive Committee chosen to-day can take this matter up and carry it forward if you wish, or you can kill the whole question of headquarters for this association by letting it drop where it is. What is best for the association, and what is fair for all parties is for you to decide now. If you have an Executive Committee in which you have confidence, you may refer this matter to it with full powers, or you may take any other action you see fit. The good of the association as a whole is what we are all striving for, and I think I need say no more on the subject. I have given you as clear an explanation as I can of what has occurred up to this time.

I may add, for the benefit of the new members who, perhaps, do not know about it, that three or four years ago, when we had our convention in Hartford, this matter of headquarters was brought up, and some of our progressive members, who are pushing ahead all the time, thought the association should have headquarters, and at that time a committee was appointed to look into the matter. But no opportunity presented itself for obtaining headquarters, within the means of the association, until this last Summer, when it looked as though there was a chance.

Is there anything to be said upon the motion before the house, that the whole matter be left to the Executive Committee with full powers to act, with the limitation that the expense shall not be such as to increase our annual dues?

Mr. Beals. I think, in the report made day before yesterday, there was a point mentioned that you have not brought out today,

Mr. President. I understand that the Boston Society has accumulated, and is accumulating, a very valuable library, and that under this proposed arrangement the members of the New England Water Works Association will have the right to use that library, as well the library that we may gather ourselves. This would be of material value to us, because if we are seeking information, and could not find it in our library, we might, perhaps, find it in the library in the adjoining room, if we make this arrangement with the Boston Society.

The President. In our talk with the Boston Society it was understood that our members should have free access to its library, which is a very extensive and valuable one. Is there anything more to be said? We are in a hurry, but we have time enough to discuss this as long as anybody wants to talk upon it, if we don't do anything else to-day. We would be glad to hear from any member.

Mr. Sidney Smith. I hope that the association will express confidence in its new Executive Committee, and leave this matter entirely in their hands. It is a matter which has been before the Boston Society of Civil Engineers for a great many years. It is something which requires prompt action when the time comes.

Mr. G. S. Williams. It appears to me that the real question, or the question over which there may possibly be a desire to have a discussion, has not been brought before the association yet in a way to permit of its formal discussion. I think that there is not a member of the association that is not desirous of having a permanent home for the association; at the same time the question seems to be as to whether the scheme which has been proposed is a desirable one. I understand that there have been some objections raised to it. In order to bring the question before the association, and in order that the doings of the Executive Committee, now going out of office, may be either indorsed or objected to, I move as an amendment to Mr. Forbes' motion that the association indorse the action that has been thus far taken by the Executive Committee.

Mr. Noyes. Mr. President, I have refrained from speaking on this question, having spoken somewhat at length upon it the other day, but it seems to me, while I feel it to be very fitting that the action of the old Executive Committee should be approved, that the hands of the new Executive Committee should be left untied, for

the reason that some questions may come up on which it would wish to take a different action from that taken by the old Executive Committee. There has been some slight objection raised to the plan proposed, and it seems to me the new Executive Committee might, perhaps, act more deliberately and wisely if they were not hampered by any vote which it might construe as calling upon it to act directly in accordance with the action of its predecessor.

THE PRESIDENT. The motion before the house is, that the whole matter be left in the hands of the Executive Committee, with full powers to act, with the exception that the expense to the members shall not be increased. Mr. Williams' motion is in the form of an amendment, that the association indorse the action of the Executive Committee of last year.

MR. NOYES. Is it to be understood, Mr. President, that our indorsement of the action thus far taken will make it necessary for the new Executive Committee to confine itself entirely to carrying out what has already been begun?

MR. WILLIAMS. That certainly was not my intention in making the motion.

MR. NOYES. Then, of course, I will withdraw my objection to the amendment.

THE PRESIDENT. Let us understand this thoroughly. The Executive Committee, perhaps, exceeded its powers in negotiating in any manner for headquarters; but believing it was for the interest of the association that some action should be taken, and as it looked at the time as though we had got to take the matter in hand at once or lose the opportunity, we took the course that we did. If the plan had gone through, and the Boston Society had accepted the proposition we made in your behalf, we should have come before you for your indorsement to-day. So I understand that the vote now proposed. our action having been a little informal up to this point in our negotiations, is merely meant as an indorsement of the action of the committee in doing what it considered to be its duty.

Mr. Williams' amendment was adopted.

THE PRESIDENT. I thank you, gentlemen, for indorsing our action; it relieves our consciences and clears up the matter so that there is nothing obscure, and we are much obliged to Mr. Williams for seeing that point.

Now the motion before the house is that the question of head-

quarters be left to the Executive Committee with full powers to act, with the one exception of increasing the dues. Is there any other member here who wishes to speak on that question? If not, I shall put it to vote.

Mr. Forbes' motion, leaving the matter to the Executive Committee with full powers, except that the annual dues of the members must not be increased, was then unanimously adopted.

Mr. R. H. Cairns, City Engineer, Waterbury, Conn., presented and explained a series of stereopticon "Views of the New Works at Waterbury."

Mr. George H. Barrus, Civil Engineer, Boston, read a paper on "Calorific Determination of the Value of Fuel," illustrated by the use of his apparatus. The paper was discussed by Messrs. Williams, Coggeshall, Noyes, Holden, Whitney and Smith.

Mayor Van Patten, of Burlington, sent for distribution among the members an illustrated pamphlet on the city of Burlington.

On motion of Mr. Chase, a vote was passed extending the thanks of the association to His Honor, and also expressing regret at his inability to be present.

The Secretary read a paper by R. C. Bacot, Jr., Superintendent Meter Department, Port Chester, N. Y., on "Attaching and Care of Water Meters."

The convention then adjourned.

EVENING SESSION.

Albert F. Noyes, Civil Engineer, member of the Massachusetts Sewerage Commission, made an address on "The Metropolitan Water Supply of Massachusetts."

CLOSING COURTESIES.

Mr. Coggeshall. I have a number of resolutions I would like to introduce at this stage of the proceedings. And first, I move:

"That the sincere thanks of the members of this association be extended to the citizens of Burlington; R. D. Wood & Co., of Philadelphia; the Chapman Valve Manufacturing Co., of Indian Orchard, Mass.; the Hersey Manufacturing Co., of Boston, Mass., and the Thomson Meter Co., of New York, for the beautiful entertainment provided by them, and which has done much to contribute to the success of the convention."

Mr. Noyes. In seconding this motion I wish to express the

gratitude which I feel, and which I know all of the members of this association feel, for the hospitality and kindness which have been extended to them here, and the pleasure which they have experienced in accepting it. We were told some years ago, when a very cordial invitation was extended to us to come to Burlington, that we should have a good time if we came, and a profitable convention. It was thought, at that time, that Burlington was almost too far away for the convenience of our members. I do not believe that we shall ever look upon Burlington again as much farther away than our own hearthstones. I most cordially second the resolution submitted by Mr. Coggeshall.

The President called upon those who favored the resolution to manifest it by raising both hands, and declared the vote to be "a doubly unanimous vote, something which never occurred before in the history of the association."

MR. COGGESHALL. I further move "That the thanks of the members of this association are hereby extended to the National Meter Company of New York for the excursion provided, on Wednesday last, for the ladies attending this convention."

The President ruled that on this motion the ladies could vote, and the motion was adopted.

Mr. COGGESHALL. I also move "That the sincere thanks of the members of this association be extended to Messrs. F. H. Crandall and W. H. Lang, both of Burlington, for the large amount of work done by them to make the programme of this convention a success; also that thanks be hereby extended to Mrs. W. E. Hall for the beautiful flowers contributed and placed in the convention hall during the various sessions."

Adopted.

MR. COGGESHALL. And, now, Mr. President, we all know we have had a beautiful time here. This association was organized in 1882, and its first convention was held in Boston. The following year we went to Worcester, then to Lowell, then to Springfield, then to New Bedford, next to Manchester, from Manchester to Providence, from Providence to Fall River, from Fall River to Portland, from Portland to Hartford, from Hartford to Holyoke, from Holyoke to Worcester, from Worcester to Boston, and from Boston we have come here; and in the whole history of this association, I do not think we ever had a finer convention, or a more successful

one, than this has been. And one member of this association, more than any other, should have the credit of the success of our present convention. He is a member for whom we have a large amount of love and esteem, and I have been directed by my fellow members to hand these books to our esteemed friend and associate, Mr. Crandall, as a slight token of the love and respect with which he is regarded by us all. [Applause.]

Mr. Crandall. Mr. President, and Gentlemen of the New England Water Works Association, I cannot express fittingly my feelings at receiving this testimonial of your regard. I can only say that if this meeting has been successful and pleasant, it is my delight that it has been so, and that in some small measure I have, perhaps, been able to contribute to the profit and pleasure of you all. [Applause.]

Mr. Coggeshall. Now, Mr. President, I am going to make a motion, which I shall ask our Secretary to put, that the sincere thanks of the members of this association be extended to our retiring President, Mr. George A. Stacy, for the able and courteous manner in which he has presided over the business and deliberations of this association.

The motion was adopted by the members rising.

Mr. Stacy. Gentlemen of the New England Water Works Association, and Ladies, for as I understand, there is soon to be another association for our ladies, during the term of office with which you have honored me, and which I have held, under circumstances that were beyond our control, for a year and three months, there has been up to the present moment only one cause for regret on my part, and that I now experience, owing to the fact that your President elect is not here, and that I cannot have the pleasure of presenting him to you. As he is not here personally, I am not able to speak fittingly for him, but he is known to you as a man who is eminent in his profession, who has long been an interested and active member of this association, and is a man who would be a credit, either as a member or an officer, to any association in the world. I heartily commend your judgment in the selection you have made.

And now, as I am about to lay down the gavel for the last time, I want to extend to you the thanks, which I feel are due to you, for the very able and kindly manner in which you have supported me

throughout the year and three months in which I have held this office, and which has made possible the holding of this convention, which has been the grandest ever held by our association. I want to thank you for your work to-day. I do not think I ever attended a convention in which the members kept at their work so well, and did so much, especially when we consider the great attractions outside to draw them away to visit the beautiful surroundings with which this place is favored. Our records, I think, will show that we have done as much, if not more, business than at any other convention we have ever held. Now, in leaving my office, and laying down the responsibility and work, I do it with a deep sense of obligation to you for your support and interest. I only ask of you, in behalf of the President elect, that you will give him the same support that you have given me and to your other presidents, and if you do that the success and prosperity of the New England Water Works Association is assured. I thank you all again for your attendance here, and your attention, and express the hope that we shall all work together harmoniously in the future as we have in the past.

Is there any other business to come before the association at this time?

MR. COGGESHALL. I move that the thanks of this association be extended to our Secretary, Mr. Whitney, for the conscientious and able manner in which he has attended to the duties of his office.

THE PRESIDENT. It is with great pleasure I put that motion expressing our appreciation of the man who is the sheet anchor of this association. Adopted.

THE PRESIDENT. Now, Mr. Whitney, a speech. [Applause.]

MR. WHITNEY. Mr. President, I think I understand what the applause means; it means you only want a very few words from me. I certainly thank the members for their very kind reception, and I feel that I owe very much more to them than they do to me.

MR. CHACE. I move the thanks of this association be given to the retiring senior editor, Dexter Brackett, for his services. Adopted.

On motion of Mr. Richards, the convention adjourned.

SOCIAL FEATURES.

The social features of the convention were unusually interesting and varied.

On Wednesday, by invitation of the National Meter Company, the ladies of the party enjoyed an excursion on the steamer down the lake to Fort Ticonderoga and return and dinner on the steamer.

On Thursday, through the courtesy of the citizens of Burlington, R. D. Wood & Co., the Chapman Valve Manufacturing Company, the Thomson Meter Company, and the Hersey Meter Company, members and guests numbering 180 were treated to a trip through the Ausable Chasm and dinner at the Hotel Champlain. The party proceeded across the lake to Port Kent, where cars were taken to the chasm. Several hours were spent in viewing the inspiring scenery of the chasm and a boat ride down the rapids, during which several members received an involuntary shower bath, after which the party were conveyed by carriage and rail to the magnificent Hotel Champlain. After dinner the return was made by steamer to Burlington.

On Friday afternoon a trip was made on special trolley cars to Fort Ethan Allen. There the operation of an air lift pump was inspected. The pump which is used to supply the U. S. government barracks takes water from two wells of 6-inch and 8-inch diameter, and over 300 feet deep. The water is lifted, by the air lift pump, at the rate of 5,000 gallons per hour, from a depth of about 140 feet to the surface, after which it is raised by a steam pump to a stand-pipe 85 feet high.

From the pump attention was turned to the cavalry post which was inspected in all its details. Lieut. Tate kindly brought out a squad from Troop F, that went through the Cossack drill. After witnessing dress parade the party returned to the city.

Most of the party departed by the morning trains on Saturday; all with pleasant memories of "Beautiful Burlington" and its hospitable citizens.

LIST OF EXHIBITS BY ASSOCIATE MEMBERS AT THE CONVENTION.

UNDER CHARGE OF W. H. LANG.

Chapman Valve Mfg. Co., Indian Orchard, Mass., Valves and Hydrants.

Crosby Steam Gage and Valve Co., Boston, Mass., Gages and Valves.

Hersey Mfg. Co., South Boston, Mass., Meters.

Lead Lined Iron Pipe Co., Wakefield, Mass., Service Pipe and Fittings.

Lang, Goodhue Co., Burlington, Vt., Flexible Pipe Joint.

H. Mueller Mfg. Co., Decatur, Ill., Brass Goods and Tapping Machines.

National Meter Co., New York, Meters.

Neptune Meter Co., New York, Meters.

Peet Valve Co., Boston, Mass., Valves.

Pittsburg Meter Co., Pittsburg, Pa., Meters.

Ross Valve Co., Troy, N. Y., Valves.

Anthony P. Smith, Newark, N. J., Main Pipe Tapping Machine.

Benj. C. Smith, New York, Cast Iron Pipe Cutting Machine.

Thomson Meter Co., Brooklyn, N. Y., Meters.

Union Water Meter Co., Worcester, Mass., Meters.

Walworth Mfg. Co., Pipe Cutters, Tapping Machines and Brass Goods.

H. R. Worthington, New York, Meters.

R. D. Wood & Co., Philadelphia, Pa., Drawings of Hydrants.

ATTENDANCE AT THE CONVENTION.

ACTIVE MEMBERS.

Abbott, E. L., Brookline, Mass.
Amerman, Lemuel, Scranton, Pa.
Baldwin, Chas. H., Boston, Mass.
Bancroft, Lewis M., Reading, Mass.
Barrus, George H., Boston, Mass.
Batchelder, G. E., Worcester, Mass.
Beals, Joseph E., Middleboro, Mass.
Bigelow, James F., Marlboro, Mass.
Bisbee, F. E., Auburn, Me.
Burke, James E., Princeton, N. J.
Cairns, R. A., Waterbury, Conn.
Chace, George F., Taunton, Mass.
Chadbourne, E. J., Wakefield, Mass.
Chandler, Henry, Manchester, N. H.
Chase, John C., Wilmington, N. C.
Codd, W. F., Nantucket, Mass.
Coggeshall, R. C. P., New Bedford, Mass.
Cook, Byron I., Woonsocket, R. I.
Crandall, F. H., Burlington, Vt.
Crandall, George K., New London, Conn.
Crowell, George E., Brattleboro, Vt.
Davis, J. M., Rutland, Vt.
Dotten, W. T., Winchester, Mass.
Drake, B. F., Laconia, N. H.
Dyer, E. R., Portland, Me.
Eastman, H. E., Westport, N. Y.
Fish, J. B., Scranton, Pa.
FitzGerald, Desmond, Boston, Mass.
Forbes, F. F., Brookline, Mass.
Foster, Joel, Monpelier, Vt.
Gilbert, J. C., Whitman, Mass.
Gilderson, D. H., Bradford, Mass.
Giles, Jason, Indian Orchard, Mass.
Gleason, Fred. B., Marlboro, Mass.
Glover, Albert S., Boston, Mass.
Gow, Fred. W., Medford, Mass.
Graham, J. W., Portland, Me.
Greene, S. C., St. Albans, Vt.
Hammatt, E. A. W., Boston, Mass.
Harrington, George W., Wakefield, Mass.
Haskell, John C., Lynn, Mass.

Hastings, V. C., Concord, N. H.
Hazen, Allen, Boston, Mass.
Hayes, A. G., Middleboro, Mass.
Holden, H. G., Nashua, N. H
Huntington, James A., Haverhill, Mass.
Hyde, H. N., Newton, Mass.
Jones, J. A., Stoneham, Mass.
Kempton, David B., New Bedford, Mass.
Kent, E. W.,, Woonsocket, R. I.
Kent, Willard, Narragansett Pier, R. I.
Kieran, Patrick, Fall River, Mass.
Knowles, Morris, Boston, Mass.
Locke, James W., Brockton, Mass.
Lockwood, Joseph A., Yonkers, N. Y.
McIntosh, H. M., Burlington, Vt.
McNally, William, Marlboro, Mass.
Nash, H. A., Jr., Boston, Mass.
Naylor, Thomas, Maynard, Mass.
Northrop, F. L., Milford, Mass.
Noyes, Albert F., Boston, Mass.
Parks, Charles F., Boston, Mass.
Rice, J. L., Claremont, N. H.
Richards, W. H., New London, Ct.
Ries, George J., Weymouth, Mass.
Rogers, H. W., Haverhill, Mass.
Russell, Daniel, Everett, Mass.
Salisbury, A. H., Lawrence, Mass.
Sanborn, Willard T., Dover, N. H.
Sealy, W. F. P., Potsdam, N. Y.
Sedgwick, W. T., Boston, Mass.
Shepard, F. J., Derry, N. H.
Smith, H. O., Leicester, Mass.
Smith, Sidney, Rutland, Vt.
Stacy, Geo. A., Marlboro, Mass.
Stoddard, S. G., Jr., Bridgeport, Ct.
Swain, Geo. F., Boston, Mass.
Tenney, J. G., Leominster, Mass.
Thomson, John, New York, N. Y.
Thomas, R. J., Lowell, Mass.
Thomas, W. H., Hingham, Mass.
Wallace, E. L., Franklin, N. H.
Walker, Chas. K., Manchester, N. H.
Warren, H. A , St. Albans, Vt.
Watters, Joseph, Fall River, Mass.
Welch, J. Alfred, Methuen, Mass.
Whitney, J. C., Newton, Mass.
Whittemore, W. P., No. Attleboro, Mass.
Williams, G. S., Detroit, Mich.
Winslow, George E., Waltham, Mass.
Zick, W. G., Brooklyn, N. Y.

Total active membership present, 91.

HONORARY MEMBERS.

The Engineering News, of New York City, by M. N. Baker.
The Engineering Record, of New York City, by Charles J. Underwood, Jr.
Fire and Water, of New York City, by F. W. Shepperd.

Total honorary membership present, 3.

ASSOCIATE MEMBERS.

Chadwick Lead Works, Boston, Mass., by A. H. Brodrick.
Chapman Valve Co., Indian Orchard, Mass., by E. L. Ross.
Deane Steam Pump Co., Holyoke, Mass., by Chas. P. Deane, F. H. Hayes and J. E. Bachelder.
Hersey Mfg. Co., Boston, Mass., by J. E. Spofford and Jas. A. Tilden.
Ingersoll–Sergeant Co., Boston, Mass., by M. S. Harlow.
Lang & Goodhue Co., Burlington, Vt., by W. H. Lang.
McNeal Pipe and Foundry Co., Burlington, N. J., by Wilmer Reed.
Mass. Chemical Co., Boston, Mass., by A. R. Baldwin.
Chas. Millar & Co., Utica, N. Y., by F. D. Fisk.
Mueller Mfg. Co., Decatur, Ill., by Adolph Mueller and A. H. Barber.

National Meter Co., New York City, N. Y., by J. G. Lufkin.
Peet Valve Co., Boston, Mass., by S. B. Adams.
Pittsburg Meter Co., Pittsburg, Penn., by A. L. McKaig.
Ross Valve Co., Troy, N. Y., by Wm. Ross, Secretary.
Anthony P. Smith, Newark, N. J., by W. H Van Winkle,
Benj. C. Smith, New York City, N. Y., by Fred. A. Smith.
Thomson Meter Co., Brooklyn, N. Y., by Henry C. Folger.
Union Meter Co., Worcester, Mass., by John C. Otis and J. P. K. Otis.
Walworth Mfg. Co., Boston, Mass., by J. H. Eustis and B. Frank Polsey.
R. D. Wood & Co., Philadelphia, Penn., by Jesse Garrett and J. H. Marshall.
Henry R. Worthington, New York City, by J. M. Betton and Geo. B. Ferguson.

Total associate membership present, 29.

GUESTS.

Abbott, E. L Mrs., Brookline, Mass.
Ammerman, L. Mrs., Scranton, Pa.
Baker, M. N. Mrs., New York City.
Bancroft, Louis M. Mrs., Reading, Mass.
Barrows, John H., New Bedford, Mass.
Barrows, John H. Mrs., New Bedford, Mass.
Batchelder, G. W., Worcester, Mass.
Batchelder, F. R. Mrs., Worcester, Mass.
Beals, Joseph E. Mrs., Middleboro, Mass.
Brightman, Charles P., Fall River, Mass.
Brown, N. K., Burlington, Vt.
Catlin, Fred. J., Flint, Mich.
Chace, G. F. Mrs., Taunton, Mass.
Chase, Fred. A., Providence, R. I.
Chase, Helen G. Miss., Providence, R. I.
Chase, J. C. Mrs., Wilmington, N. C.
Coggeshall, R. C. P. Mrs., New Bedford, Mass.
Crandall, F. H. Mrs., Burlington, Vt.
Crandall, George K. Mrs., New London, Conn.
Creighton, C. Mrs., Fall River, Mass.
Davis, Mrs., St. Albans, Vt.
Dwyer, Thomas E., Wakefield, Mass.
Evans, J. M., Burlington, Vt
Fish, J. B. Mrs., Scranton, Pa.
Forbes, F. F. Mrs., Brookline, Mass.
Giles, Jason Mrs., Indian Orchard, Mass.
Hall, W. E., Burlington, Vt.
Holden, H G. Mrs., Nashua, N. H.
Hope, B. B., Middlesex, Vt.
Kempton, David B. Mrs., New Bedford, Mass.
Kent, E. W. Mrs., Woonsocket, R. I.
Kent, Willard Mrs., Narragansett Pier, R. I.
Lang, George L., Burlington, Vt.
Lang, W. H. Mrs., Burlington, Vt.
Langworthy, A. H., Middlesex, Vt.
Macain, George, Milford, Mass.
McNally, William Mrs., Marlboro, Mass.
Mann, George E., Woodsville, N. H.
Marvin, Charles, Worcester, Mass.
Milne, Peter, Brooklyn, N. Y.
Nash, Miss, Boston, Mass.
Naylor, Thomas Mrs., Maynard, Mass.
Parks, C. F. Mrs., Boston, Mass.
Parks, Louise S. Miss, Boston, Mass.
Prescott, S. C., Boston, Mass.
Reed, Wilmer Mrs., Burlington, N. J.
Richards, W. H. Mrs., New London, Conn.

Ries, George J. Mrs., Weymouth, Mass.
Rogers, H. W. Mrs., Lawrence, Mass.
Ross, E. L. Mrs., Indian Orchard, Mass.
Salisbury, A. H. Mrs., Lawrence, Mass.
Sanborn, W. T. Mrs., Dover, N. H.
Sanctuary, E. N. Burlington, Vt.
Sawyer, H. T. Medford, Mass.
Shepard, F. J. Mrs., Derry, N. H.
Small, S. J. Miss, New Bedford, Mass.
Smith, H. O. Mrs., Leicester, Mass.
Spofford, J. E. Mrs., Boston, Mass.
Stacy, George A. Mrs., Marlboro, Mass.
Storrs, H. A. Burlington, Vt.
Sullivan, William F. Mrs., Dover, N. H.
Swain, George F. Mrs., Boston, Mass.
Temney, J. G. Mrs., Leominster, Mass.
Thomas, H. L., Hingham, Mass.
Wallace, E. L. Mrs., Franklin, N. H.
Walling, W. H., Potsdam, N. Y.
Warren, H. A. Mrs., St. Albans, Vt.
Watters, Joseph Mrs., Fall River, Mass.

Total number of guests, 68.
Total attendance registered, 191.

ELECTROLYSIS.

BY

PROFESSOR H. A. STORRS, University Vermont, Burlington, Vt.

[Read Sept. 11th, 1895.]

Members of the New England Water Works Association, Ladies and Gentlemen:

When I consented last June, to present a paper at this meeting, I was planning a series of experiments which I hoped would add some interesting facts to those already known in regard to the electrolysis of underground pipes by return currents from electric railways. But a serious accident to my eyes in July upset my plans; so that what I now have to offer is simply a brief statement of some practical information on the subject, gleaned from technical publications during the past year or two, and including some hints which I trust will prove of practical value to practical men.

I have selected three heads under which to group the remarks I have to make in regard to the destructive action of electric currents on underground pipes.

First. Remedies in the case of cities where electric roads are already in operation.

Second. Preventive measures for cities where roads are yet to be installed.

Third. Some of the legal aspects of the subject.

With few exceptions the electric roads now operating in this country use the "single trolley system." The overhead wires, including trolley wires and feeders, form one side of the circuit; the rails, the earth, conductors called "return feeders," and too often water and gas pipes constitute the other side of the circuit, the two being connected through the cars in operation. On roads of this kind the positive side of the generator should be connected to the overhead system of conductors. The current then flows from the

generator through the feeders to the trolley wire, thence down the trolley pole through the motors and trucks to the rails, thence back to the negative side of the generator by any and every path available. Now to prevent the current from returning by way of the pipes we must render it impossible for them to become easily available paths. The most easily available path is, of course, the one of greatest conductivity. If rails are properly bonded from end to end of the track and the track connected to the negative side of the generator by a wire of proper conductivity, a very large part of the electricity used by the car motors will avail itself of this easy path back to the generator. But if a considerable quantity of electricity still chooses to avail itself of the underground pipes, then additional paths must be provided in the shape of large copper wires, called the return feeders. These are attached at frequent intervals to the rails and are carried, either underground or overhead, back to the negative side of the generator. These form additional paths of high conductivity and are, therefore, easily available for the return currents.

But even when a goodly number of return paths have been thus provided the electric currents still choose, with that perversity we ascribe to inanimate things, to avail themselves in a measure of the pipes which lead in the direction in which they tend to flow. If we examine this path back to the generator, by way of the pipes, we find that the electricity must first pass from the rails through a stratum of moist earth in order to reach the pipes, then pass along the pipes as far as they offer an available path, then leave the pipes, and pass again through a stratum of moist earth back to the rails, return feeders or other conductors and eventually reach the negative side of the generator.

This stratum of earth is of relatively low conductivity and when dry renders the return path, by way of the pipes, almost unavailable for the return current. Even when moist it offers considerable resistance to the electric current and to that extent acts as a shield to the pipes, tending to prevent electricity from leaking to them. And since we desire so far as possible, to prevent electricity from getting to the pipes, we must ascertain where the localities are at which electricity tends to leak from the rails to the pipes and there preserve our shield of earth intact. Evidently to connect the rails to the pipes by means of wires in these localities is just what ought not to be done.

Yet this has been done in numberless cases and much mischief has been done thereby. Railway companies have bonded their tracks to pipes for the purpose of using the latter as an aid to their ground return. In this way enough electricity has sometimes been caused to flow through a pipe line to set fire to the oakum which workmen were using in caulking a joint. Metallic connections are also sometimes made accidentally from track to pipes by service pipes being permitted to touch some portion of the tracks. Water and gas pipes have sometimes been indiscriminately bonded to tracks under the mistaken notion that injury to pipes would be prevented thereby.

The general rule may be laid down that where electricity tends to pass from the track to the pipes, or, technically speaking, where the track is "positive to the pipe," or where the track is of "higher potential than the pipes," there metallic connections should be avoided; our first aim being to keep the pipes out of reach of electrical currents so far as possible. It therefore becomes necessary to ascertain the localities in which tracks are "positive to pipes." For this purpose a voltmeter, reading to hundreths of a volt, is required, and where pipes are not accessible, tests between the rails and fire hydrants may be relied upon to give reasonably accurate results.

In spite of all precautions, however, there will generally be sufficient leakage from the track to the pipes to cause trouble. For any electricity that has found its way into the pipes must also find its way out, and if no better path is available it will pass out of them into the moist earth around them. Wherever this occurs electrolytic action will result; for the earth found under city streets is usually impregnated with water holding in solution salts of the alkaline earths which are easily decomposed by electricity. Now one of the products of this electrolysis is an acid radical which combines with the iron of the pipe from which the current is flowing and forms a ferrous salt. This ferrous salt diffuses through the damp soil thus carrying away iron from the pipes and eventually destroying them. The electrolysis of water requires a difference of potential of about one and a half volts. But electrolysis of such salts as are common in the soil of city streets, has been found to take place where the measured difference of potential was only one thousandth of a volt†, showing that a mere "directive force" is sufficient to cause the action.

†Trans. Am. Inst. Elec. Eng. Vol. XI., p. 237.

But electrolytic action will not occur if the electricity leaves the pipe by a metallic path. Therefore, having ascertained by the aid of a volt-meter the localities where electricity tends to leave the pipe—that is, where pipes are positive to the surrounding earth and neighboring conductors, we proceed to attach to them special return feeders of sufficient size to easily carry back to the generator all the electricity flowing in the pipes.

Having thus outlined the theory and practice of dealing with this danger to underground pipes, I will quote from a paper* of Mr. I. H. Farnham, to whom belongs the honor of having first described and applied this method of protecting pipes from electrolytic action, the conclusions he arrived at as a result of his careful series of experiments:

"First. All single trolley railways employing the rails as a portion of the circuit, cause electrolytic action and consequent corrosion of the pipes in their immediate vicinity, unless special provision is made to prevent it.

"Second. A fraction of a volt difference of potential between pipes and the moist earth surrounding them, is sufficient to induce the action.

"Third. Bonding the rails, or providing a metallic return conductor equal in sectional area and conductivity to the outgoing wires, is insufficient to wholly prevent damage to pipes.

"Fourth. Insulating pipes sufficiently to prevent the trouble is impracticable.

"Fifth. Breaking the metallic continuity of pipes at sufficiently frequent intervals is impracticable.

"Sixth. It is advisable to connect the positive pole of the dynamo to the trolley lines.

"Seventh. A large conductor, extending from the grounded side of the dynamo entirely through the danger territory, and connected at every few hundred feet to such pipes as are in danger, will, usually, ensure their protection.

"Eighth. It is better to use a separate conductor for each set of pipes to be protected.

"Ninth. Connection only at the power station to water or gas pipes will not ensure their safety.

"Tenth. Connection between the pipes and rails, or rail-return wires outside the danger district, should be carefully avoided.

*Trans. Am. Inst. Elec. Eng., Vol. XI., p. 191.

"Eleventh. Frequent voltage measurements between pipes and earth should be obtained, and such changes in return conductors made as the measurements indicate."

Referring to conclusion fifth, it is often found that at pipe joints, where metallic continuity has been accidentally interrupted, intense electrolytic action has occurred.

Referring to conclusions seventh and tenth, the "danger territory" includes all the territory wherein the pipes are positive to the surrounding earth. In cities containing but one power station, the danger territory is usually confined to the immediate vicinity of the station, its area depending upon the extent to which the tracks are properly bonded and return feeders installed.

So much depends upon having good electrical contact between the pipes and the return feeders, that I present a sketch (Fig 1.) of the clamp for attaching a wire to a water main, devised by Mr. M. G. Starrett, chief electrician of the Brooklyn city railway, and thus described*: "The collar is of wrought iron, in two parts, $\frac{5}{8}$ of an inch thick, and two inches broad. The two parts are drawn together by $\frac{3}{4}$ inch bolts, with two nuts to each bolt. The collar is previously turned out upon its inner face to $\frac{1}{4}$ of an inch larger diameter than that of the pipe to which it is to be applied. Midway in one part is formed a lug, into which is brazed a No. 00 copper wire. In applying the connection the pipe is carefully brightened all around with a file. A strip of bright lead $\frac{5}{32}$ of an inch thick and $2\frac{1}{2}$ inches broad, is laid around the pipe, and the collar is clamped down by the bolts until the lead gasket is meshed into the inequalities of the pipe. The lines of juncture between the collar and lead and pipe are thickly painted over with "P. & B." mixture, then carefully taped over and again painted with "P. & B." upon the tape, after which the whole is thoroughly packed in with good cement." The thoroughness of this method is not deemed excessive, in view of the requirements of the case, since the efficacy of this remedy for electrolytic action depends largely on maintaining good electrical contact here. Where cast iron pipes are used, reliable connection may be obtained by tapping a $\frac{3}{4}$ inch hole and inserting a brass plug, to which the copper return wire may be thoroughly soldered.

*Electrical World, Vol. 25, p. 72.

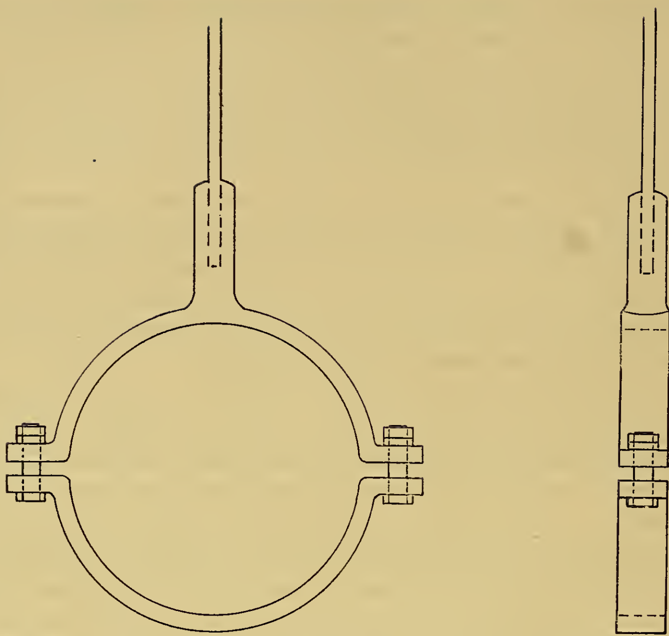


FIG. 1.

Under the second head, viz.: preventive measures in the case of cities where electric roads are yet to be installed, I wish to point out first, that the *kind* of electric railway system chosen will itself determine, to a large extent, the preventive measures required. If it is to be the single trolley system, such as we have been considering, then the track should be heavily bonded, or rails welded together, ample return feeders should be provided, and after the road is in operation, all underground pipes should be properly connected to return feeders at points located by careful tests as before described. The three-wire single trolley system is recommended by some as not being dangerous to underground pipes because the rails are "neutral," one portion of the trolley wire constituting the path for the outgoing current from the station and another portion constituting the return path. But the fact still remains that the current must pass through the rails for longer or shorter distances, depending upon the position and movement of the cars. Consequently leakage to and from the pipes is likely to

occur, but just where, or in how short a time destructive action on the pipes would result, it would be difficult to foresee. The danger territories would not be confined to the vicinity of the power stations as in the case of the single trolley system, but would be broken up into numerous indefinable and ever shifting districts, rendering it impracticable to apply the remedial measures hereinbefore described.

Briefly it may be stated that every direct current system that uses the earth or any conductor in contact therewith as part of its electrical circuit is dangerous to underground pipes. This covers all trolley systems except on elevated roads where the entire electrical system is insulated from the elevated structure or from the earth.

The "double trolley," the "conduit" and the "storage battery" systems, on the other hand, are not dangerous to underground pipes, because their electrical circuits are normally not in contact with the earth at any point. But questions of first cost, practicability, etc., present themselves very forcibly to railway companies when the adoption of any of these systems is recommended, and in a majority of cases the "single trolley ground-return system" will be chosen for some time to come unless state or municipal authority regulates the matter.

How soon such legislative action will be taken in this country it would be difficult to predict; but it may be of passing interest to note that recent news reports from Japan state that the municipal authorities of Tokio have decided to avoid the electrolytic corrosion of existing water pipes by compelling the use of the double trolley over the projected 85 miles of roads in that city. Double trolley roads have been in successful operation for years in several American cities, notably in Cincinnati.

As to the practicability of the conduit system, a recent number of the *Electrical World* states that as a result of the great satisfaction given by the Lenox Avenue Conduit Electrical Railway, during several months operation in New York City, it was announced last week by the officials of the Metropolitan Street Railway Company that horses and cables would be abandoned and all its lines of street railroad would be equipped for operation by electric power.

All the preceding systems use the direct current; that is the current flows steadily in one direction through the circuit. Now if it

were possible to reverse the direction with sufficient frequency injuries to pipes would be avoided. But a reversal every week, or every day, or every hour, would not be sufficient. Possibly a reversal every minute would answer, though one every second would be safer. But a current whose direction is reversed every second, or four or five times per second, is called an alternating current. This, then, is another means for preventing destruction of pipes, namely, to adopt the alternating current instead of the direct. Unfortunately it is not feasable to do this at present as no complete railway system using alternating currents has yet been placed on the market. There is good reason to hope, however, that this will not be the case a year hence, and then one more system will be added to the list of those which may be installed in a city without being a continual menace to the much-afflicted pipes.

There remains to be considered under the third head the question usually propounded by the water works man who has listened to a description of the way in which his pipes are being destroyed by railway currents and the means for locating and preventing the trouble, namely: "Who is to foot the bill?"

Now I shall not presume to offer any off-hand answer to this important question, the courts alone being authorized to render the final decision. But it may be interesting to refer to the case of a telephone company versus an electric railway company in the Superior Court of Cincinnati, January, 1891, in which the verdict was as follows:

"The order of the Court will therefore be that the defendant be enjoined perpetually from the use of the system of electric railway propulsion as now operated by them, or any other which will occasion similar disturbances to those now caused by the defendant's single trolley system."

In this case it was the chief contention of the defendant that "because it had full power to operate by electricity under the law, therefore it could not be held liable for damages resulting therefrom, such loss to plaintiff, being in legal parlance, *damnum absque injuria*, and if plaintiff wishes to avoid the loss, it must adopt safeguards in the shape of a metallic circuit to avoid the difficulty." Now this way out of the difficulty was open to the telephone companies, and has been generally adopted by them; chiefly, however, to protect themselves against inductive disturbances from electric

lighting as well as railway circuits. But no corresponding remedy applicable to pipes subjected to the action of railway return currents is presented to water and gas companies. On the other hand, it is perfectly practicable for the electric railway companies to adopt the metallic circuit, that is the double trolley system, whereby the electrolytic action complained of could be wholly prevented. Furthermore, the judge states in the case referred to, that where one corporation is granted a right by legislative enactment which may be so exercised as to injure or interfere with the right previously granted to another, the presumption of law is that the legislature intended only such uses as were consistent with the rights of the first corporation. A case is then cited in which "plaintiff was a gas company which had laid its gas pipes, by virtue of a public grant, under a street which the defendant, a public corporation, was charged with keeping in repair, and upon which it used such heavy rollers as to injure the pipes of the plaintiff. The rollers used were economical and well fitted for the purpose; but it was held that unless the defendants were expressly authorized by statute to use rollers of the size and weight of those which did the injury, defendant could not justify under the duty to keep in repair which might be discharged by rollers of less weight and without breaking the pipes." I have presented this case at some length because it seems peculiarly applicable to the case under consideration, for here was a case of "a public grant to a gas company enjoyed in a certain way, followed by a grant to the defendant to exercise another grant, which, if exercised in one way, would injure the plaintiff's enjoyment of its rights, and which, if exercised in another, would not." Similarly in the case of electric railways, the act upon which the legal injury is founded is not the operation of the road by electricity generally, but the employment of that specific kind of electrical system which by reason of the use of a "ground return," inflicts injury upon gas and water pipes. Again, since facility and speed of transportation are the primary purpose or benefit, in consideration of which railway companies enjoy their franchises to use the electric current, it would be pertinent to ask whether the single trolley is superior on this score to the double trolley system. It is generally conceded that there is no marked difference between them in this respect. The adoption of the double trolley or other system not employing the ground return is, however, not the only.

though, from the electricians' standpoint, it is the best remedy for damage from corrosion. My earlier remarks have indicated a method by which the ground return may be rendered comparatively harmless to underground pipes.

In conclusion, then, it is difficult to see how the railway companies can escape the charge of negligence and responsibility for resultant injuries if it can be proved that, after being notified that injury was being done to gas and water pipes by the electric railway currents, the railway companies failed to adopt proper remedial measures.

DISCUSSION.

Mr. Winslow. In a single trolley system, as we well know, the return current goes through the rails, and the wire between the rails, and in so doing it has a chance to escape to the water pipes or other conductors which may be of considerably higher resistance, but still do take quite a quantity of the current. In the double trolley system there is supposed to be entire insulation from the ground, but I find that there are no insulators which are perfect, and some of the current is bound to escape; and, as Professor Storrs says, a very small current will do the damage; and there is more or less trouble even with the double trolley system; in some cases a good deal of trouble, on account of imperfect insulation. The damage that is done, being out of sight where it cannot be seen by the people generally, is not realized by them, and they really do not know how much it is costing them.

Now the only sure remedy that I can see consists not in improving the single trolley system or the double trolley system, but by the substitution of that which at the present time is not deemed practicable, namely, the storage battery system. In that the electricity is generated and used in the car, and there is no chance for it to travel through the pipes or any other conductor; and until this system is put into use in my opinion the public will have to stand the damage resulting from the use of existing arrangements. I think within ten years, possibly in less time, the wires which are now carrying the currents will be useless for that purpose, and our streets will be freed from them and the power to run each car will be carried on it.

Mr. Gilbert. Mr. President, I would like to ask how long it is after an electric road is put in before this damage to the pipes

which is spoken of becomes noticeable? This is something which affects nearly all of our thrifty towns, for they are all being reached by electric roads.

PROF. STORRS. Well, there is a great deal of information on the subject; that is to say, we can give many instances in which pipes have been very rapidly corroded. If I remember rightly, Mr. Barrett, the chief electrician of the Brooklyn Subway Board, states that there is one particular place in Brooklyn where a 6-inch cast-iron main was destroyed, or at least rendered unfit for use, in a very few months, I will not attempt to say how many, although I think it was within four or five. Mr. George P. Low, of San Francisco, also states that a large main pipe, an 8-inch pipe, I think, in the street in front of the station was destroyed repeatedly in a very few months, I think even more rapidly than that in the case mentioned in Brooklyn, although I am confident that in this case it was not a cast-iron pipe, but wrought iron, which is used so much on the Pacific coast. This indicates something as to the rapidity with which the damage takes place; but, of course, it might be going on so slowly in other places that it would be difficult to say at the end of 10 or 20 years whether the pipes had rusted out or had been acted upon by something in the soil itself, or whether the electric current had had anything to do with it.

In regard to that matter, I might say, it is well known that if two dissimilar metals are put into the earth, which usually contains certain salts, an earth battery is formed, which produces a small difference of potential and the current is sufficient to cause the electrolytic action; so that even if there were no electric railroad this small electric current would be continually circulating and affecting the pipes. The idea of preventive measures is that they would probably prevent rapid destruction of the pipes, and in fact they would so much delay it, and protect the pipe to such an extent, that it would be difficult to say whether the pipes had really been injured by the electric road, or whether they had been destroyed, as they normally are, through the action of such materials as are in the soil. Pipes do not last forever under any circumstances.

MR. HAZEN. Is it possible that induced currents in the pipes should prove injurious, Prof. Storrs?

PROF. STORRS. I should think there was no possibility of a current of such size as to cause any damage being induced in the pipes.

The pipes which are most likely to be injured are those near the station, because the electricity enters them at remote points and will follow them to the neighborhood of the station and will there leave them and go into the earth on its way to the station. The end of a pipe in the vicinity of a power house is very likely to be the place where the greatest electrolytic action will take place.

Mr. Fish. We have two miles of pipe with an electric railroad near it, over which cars run every seven minutes 18 hours out of the 24. I have not discovered any damage, although I have examined for it, and although the pipe line terminates within 200 feet of the power house. I thought that was what was helping it, but I may be wrong about it.

Mr. Chase. There is another question which I fancy may be of interest to water works men present, suggested by the last remarks, and that is how small a power plant would be likely to have a detrimental effect upon the water works system. For example, would the power plant in Burlington be likely to have a detrimental effect on the water works system you have here?

Prof. Storrs. The only way to know about that is to make the test and find it out. It would depend very much on the location of the pipes, and as to how well the rails were bonded. It would be entirely indeterminate on general principles. Supt. Crandall tells me that, here in Burlington, one service pipe has been destroyed by electrolysis where it crossed the street passing close to the rails; this was near the power house. Our electric road has been running two years.

Mr. G. S. Williams. Mr. President, I am happy to say that in the city of Detroit we have not been able to determine that we have had any results from electrolysis, but on the other hand we are not able to see any reason why we should not have. As near as we can find out all the conditions required for producing these bad results are present with us. We have discovered that there is a decided difference of potential between our pipes and the rails at certain points which leads to a flow from the pipes to the rails, and at other points we have found where the current is going into the pipes. Portions of our electric railway system have been in operation for over five years, and the part which has been in operation longest has been depending for its bond simply upon the tie-plates of the rails, which are laid directly over a water main. And still as I say,

we have not determined that there is any electrolytic action going on. It may be, however, that the immense consumption of water in Detroit tends to obscure any additional loss that electrolysis might produce. (Laughter.)

There is one thing that has occurred to me as a possible remedy, which I would suggest. The principle upon which the electric current flows, is that it takes the easiest paths, or takes paths in inverse proportion to their resistance; that is the greater the resistance the less the flow of electricity. Now, if we can make our water mains of high resistance, there will be very little flow through them. While it is true that the damage occurs at the points where the electricity leaves the main, if the line is of high resistance very little electricity will go to it, and it has been suggested that if a joint were devised which would be virtually non-conducting or which would be a very poor conductor, it might work as a remedy against the effects of electrolysis. We know, of course, that the electricity will very readily flow through the lead in the joints, although it is not a good conductor. I do not mean that the insertion of an occasional non-conducting joint would be a remedy, but I am inclined to think if every joint in the pipe were made of a non-conducting material it would have quite a decided effect to prevent the flow of electricity through the pipes.

MR. WINSLOW. I don't know but the gentleman is right, Mr. President, but I was talking with the Superintendent of the Gas Works in Cambridge recently, a city adjoining mine, and he told me that their joints are all laid with cement, and that that is just where the trouble occurs. It is from the passing of the current from one pipe to the other. The cement between the pipes being of a higher resistance, the current passes from one pipe to the other through the earth, and the consequence is that the pipes are very badly eaten and a great deal of trouble is caused. And so with cement-lined pipe, which a great many of us know about, more especially the bell and spigot form, the style which was made several years ago. The spigot end of one pipe is put in the bell of the other, and that brings the iron against the cement lining, the space between is filled with cement and it is then covered with cement, so that there is practically a cement insulation. And I know that in case of lightning striking the pipe, the pipe almost invariably bursts at those points and not in any other place. So I would not favor

any attempt at insulating the joints to prevent the action of the electric current on the pipes.

Mr. Williams. I would like to say, Mr. President, that this is just the kind of information I have been looking for.

Mr. Gilbert. It seems to me, Mr. President, this subject is in rather a crude state as yet, but it looks very reasonable and very natural that electricity from the trolley wires should get at the pipes. Yet when we look around the country, wherever we find a smart town nowadays it has an electric railroad and it almost always has a system of water works, and in many cases the railroad tracks are laid directly over the water pipes. Most of us are familiar with towns that have had these electric roads for the last five years, and yet, in many of them, no damage to the pipes has yet been observed, although it does not follow that if the pipes were taken up it might not be found they had suffered from the action of the electric current We must have water pipes and we must have electric roads, and I suppose the time will come probably when we shall find out just how to manage it, but evidently there is something yet to be learned.

Mr. Milne. I was much pleased, Mr. President, with Professor Storr's paper, and I think it touches the root of the matter. I come from Trolleyville, called Brooklyn, and allusion has been made to some of the characteristics of electrolysis as we have experienced its action in that city. What the Professor remarks is true regarding a composite metal incorporated in a service pipe. Take, for instance, a galvanized iron pipe. There is naturally a galvanic action there, without any aid from trolley currents, to produce a rapid deterioration in the pipe. That is our experience in the city of Brooklyn. Perhaps the greatest potential of the entire electric railway system of Brooklyn is concentrated in Third avenue. On that line there are many galvanized iron service pipes, and their destruction after the introduction of the electric railway was very marked. Now the legal aspect of this matter is a very serious one, and it is just at this point that municipalities will have to deal with the electric railway companies in court; that is, to determine what amount of electrolysis pure and simple, caused by the electric current, takes place in these service pipes; and that is the study of the electric subway commission today in the city of Brooklyn. Now, regarding our large mains, one incidental case has been men-

tioned here, but I am not altogether satisfied that it was due entirely to the action of electrolysis. It may have been in some respects, and not in others. But at all events we have had sufficient experience to protest against Superintendent Starrett's joints being placed upon our main pipes for the purpose of removing the negative current. We have steadily adhered to the principle of keeping our mains intact from the trolley wire connections. City Engineer George H. Benzenberg, a man well known to many people here, had a very sad experience in Milwaukee when it permitted the negative wires to be attached to the water mains. It resulted in considerable trouble, and the connections were abolished. The consensus of opinion of all water works men through the country, who have studied the subject carefully, is that it is unwise to allow any electric negative connection to be made with our water mains.

Prof. Storrs. I only want to say that this method which I presented seems to have met with a good deal of favor, and if certain elements in the method may have been applied to a certain extent in some cities without producing good results, I do not think that should be taken as conclusive evidence as to the inefficacy of the method, as a whole, when it is properly applied; which involves proper bonding of the rails and the provision of ample return wires, so as to reduce the danger territory to the smallest area possible, bringing it down very close to the vicinity of the power-house; and then running the return feeders from the pipes in that danger territory into the power station.

Mr. Crandall. Do I understand you, that in your opinion in some of these instances, where wires have been attached to the pipes for the purpose of lessening the danger to the pipe, that they have been so placed as to have increased rather than diminished the damage?

Prof. Storrs. Oh, yes. It is an essential of the method that no wire should be placed between the rails and pipes where the current tends to flow from the rails to the pipes. It is very easy to cause more trouble than is prevented if the remedy is not properly applied.

CALORIFIC DETERMINATION OF THE VALUE OF FUEL.

BY

GEO. H. BARRUS, C. E., BOSTON, MASS.

[Read Sept. 13th, 1895.]

There are two systems of measurement employed in the determination of the calorific value of coal, which are in more or less common use. The first, and most widely known, is that which is based on a chemical analysis of the fuel, and the second is that obtained by calorimeter test.

Chemical analysis furnishes an indirect method of accomplishing the object, inasmuch as it first involves a determination of the component elements in the coal, and afterwards a computation of the heat of combustion of the complex body by adding together that of the various constituents. The calorific value of the elements of which coal is composed, such as carbon, hydrogen and sulphur, was originally determined by the use of a calorimeter, so that in reality the employment of chemical analysis is but another method of calorimeter measurement, although it obtains the result in a roundabout way.

The calorimeter test determines the calorific value of the coal by actually burning it, and measuring the quantity of heat which is generated in the combustion. It furnishes a direct method of accomplishing the desired object.

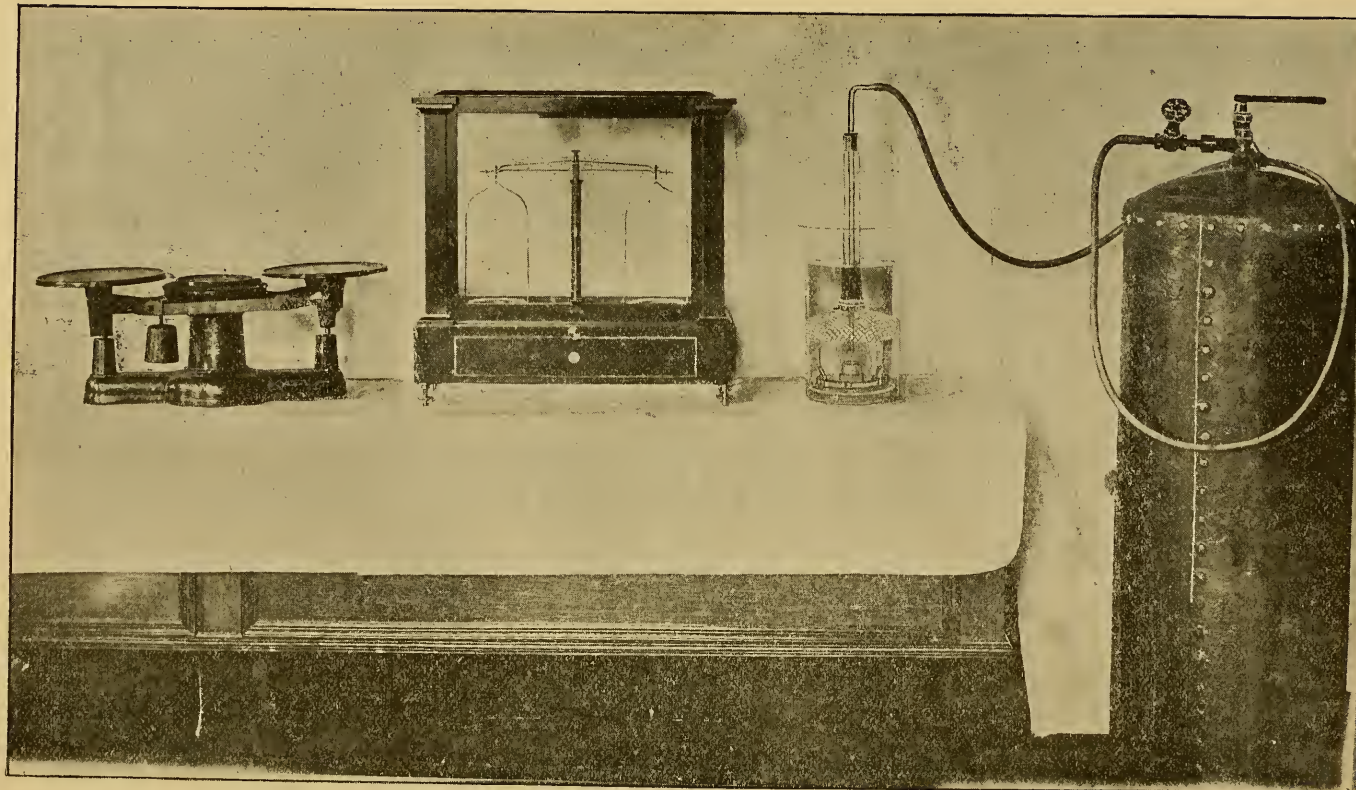
This subject is not a new one, but it does not seem to have awakened much interest amongst engineers until a comparatively recent date. It is now coming to be regarded as of considerable importance, and this is a reason for bringing the matter to the notice of the association. In doing this it is not my purpose to enter upon an extended discussion of the general subject of calorific determinations of coal. My object is rather to show the actual process of making these determinations, and exhibit the apparatus at work. It is to be hoped that the exhibition will be of some interest

as a novelty, if nothing more; but apart from this it may serve in some measure to popularize the calorimeter method of testing coal, which at the present time seems to be of growing importance.

I think everyone will agree with me, whether familiar with the subject or not, that it is desirable to have a standard of comparison by which to judge of the real value of fuel. Differences in the conditions under which coal is burned in the boiler furnace, and differences in the efficiency of the boiler itself, make it impossible to judge of the value of the fuel, if dependence is placed simply upon the results obtained with it in practice. The calorimeter test furnishes a standard which is unaffected by variations in the conditions noted. It does not furnish all the information needed to judge of the value of the fuel in practical work, but it eliminates the conditions subject to variation, and at least brings the indications as to the value of the fuel down to a uniform basis. This is a result which it is certainly worth while to achieve, and although this work may seem to those who are unfamiliar with it as belonging to the theoretical department of steam engineering, it has, in reality, a wide practical application.

The form of apparatus here shown is one which I have employed during the past five years. It has been used in testing nearly all the principal varieties of coal mined in this country. The results obtained from the various coals which have been tried with it range, from 8,500 B. T. U. per pound of coal, to 15,221 B. T. U. per pound of coal, the former being a sample of Illinois bituminous coal, and the latter, New River semi-bituminous coal from Virginia. The figures for the same coal based on combustible were 12,839 for the former, and 15,334 for the latter. The former had 33.8 per cent. ash, and the latter a trifle less than one per cent. The results obtained from other coals lie between these extremes.

As will be seen by inspection, the instrument is of rather simple construction, consisting in the main of a glass beaker and another glass vessel bell shaped, which forms the combustion chamber in which the fuel is burned. The base of the combustion chamber is of metal, and is held to the upper part of the chamber by means of spring clips, so that the two parts can be readily disconnected. The coal is burned in a platinum crucible which rests in an elevated position at the top of the base, and dependence is placed upon a current of oxygen which enters through the small glass tube inside,



APPARATUS FOR TESTING THE CALORIFIC VALUE OF COAL.

for supporting the combustion. When the instrument is working, the combustion chamber is submerged in water in the glass beaker. The pressure of the current of oxygen passing into the chamber serves to keep the water out of the interior. The gas which is formed during the process of combustion passes downward through the perforations in the base, and escapes to the surface of the water, bubbling up through the intermediate space. A wire screen surrounding the combustion chamber intercepts the bubbles of gas, and thus aids in the transfer of heat to the water. In making the test the essential data which is sought is the number of degrees of temperature which a certain weighed quantity of water is raised by the combustion of a certain weighed quantity of coal. The quantity of water generally used is one kilogram, that is 2000 grams. The quantity of coal, a single gram. With this relation of weights, and the proper allowance for the calorific equivalent of the material of the calorimeter the heating of the water one degree Fahrenheit represents in this instrument about 2150 heat units. The rise of temperature for a good quality of coal would thus lie between 6 and 7 degrees Fahrenheit. The thermometer used in determining the temperatures is graduated to fiftieths of a degree, and it can be read to hundredths. To eliminate the effect of radiation either inward or outward, the temperature of the water is so adjusted at the beginning that the temperature of the atmosphere lies midway between the initial and final readings.

Mr. Barrus then proceeded to illustrate the working of the apparatus using a sample of Pocahontas coal.

DISCUSSION.

Mr. Williams. Have you ever experimented with oil, Mr. Barrus?

Mr. Barrus. I have never used this apparatus with oil. Oil is so inflammable it is difficult to burn it satisfactorily. I have tried to mix it with coal and get a test that way, but I have never had occasion to experiment to any great extent in that direction.

Mr. Coggeshall. Would that be a practical apparatus to introduce in the daily work of a department at the pumping station? In other words, would an ordinary person find it very difficult to to use the apparatus so as to get accurate results?

Mr. Barrus. I will leave it to you to judge for yourself. I

think it would take a pretty careful man to make a test that could be relied upon.

Mr. Noyes. I would ask Mr. Barrus if we can assume that the value of the coal for producing heat is in a direct ratio to the results shown in this test, or whether there are not other conditions in actual work so that the relative results vary from those indicated by the test.

Mr. Barrus. I suppose you all know that by firing under different conditions the efficiency of a boiler can be varied by as much as 10 per cent., there would be even more than that, with very bad as compared with very good firing, but with different conditions of good firing there may be as much as 10 per cent. variation. For instance, you could carry heavy fires, and then again light fires and make that difference. But taking the same boiler, operated with the same capacity and employing the same system of firing, different varieties of eastern coals ought to show about the same relatively in the boiler in actual work as they do in the calorimeter. With western coals, which are very volatile, that statement does not hold good, because there is a very large amount of loss from incomplete combustion.

I was led into this line of investigation in the first place by some tests that I was making with two different kinds of boilers in different places, and with different kinds of coal, and I wished to determine the relative efficiency of the two boilers; that is, their relative economy for practical work. Without knowing the absolute calorific value of the two coals, I had no basis to start from. I made the test on one boiler, and I got different results from what I expected, and so I changed the fuel and made one test with Pocahontas coal and got inferior results. Then I used Cumberland, and the result was about seven or eight per cent. less, not even as good as I had obtained with the Pocahontas. I was dissatisfied, and this induced me to commence work in this line, and I found that by testing the two coals the difference in the calorimeter results just corroborated the difference in the result of the work of the boilers. Pocahontas on that test showed high, and the Cumberland was poor. I should not want to say from that that the Pocahontas is the best coal, although a great many of these figures do show the highest results from Pocahontas coal.

The Secretary. I would like to ask Mr. Barrus about a sample

of coal he has used, Clearfield coal, which seems to be quite high in heat units, while the coal is rated rather low among users of coals, and sells at a correspondingly low price. The record of the test would seem to indicate that the coal requires some peculiar firing: that is, that firemen generally do not get the full value of the coal.

Mr. Barrus. As I recall that particular sample, it was one sent me by some party who dealt in Clearfield coal, and I think it was selected as a particularly good sample, because I have tried Clearfield in other cases, where I took the sample myself, with not as good results. Here is one that gave 13,640 against 14,580 for the one referred to, and another one is only 12,500. I never tested a great many samples of Clearfield coal, and I do not know how they usually run, but there is a wide variation between 12,500 and 14,580.

Mr. Smith. Do you find that the tests vary considerably on different lots of coal from the same mine?

Mr. Barrus. Yes, they do. Take the Cumberland's, for example. I have a dozen varieties of Cumberland, and they run from 14,200 down to 12,900. They are not all from the same mine, but they came from the same region.

Mr. Holden. Would there be much variation in several small samples taken from the same carload of coal?

Mr. Barrus. I wouldn't trust one sample. I had one brought to me the other day that had only three-quarters of one per cent. of ash in it, and I have recently had a sample of the same kind of coal which left only half of one per cent., an amount so small I could hardly measure it. When I went to the coal pile, and obtained a sample myself, there was three or four per cent. of ash. For this work there ought to be two or three hundred pounds, from different parts of the pile, broken up and reduced, and a sample of that taken, and re-sampled and re-sampled until a small average sample is obtained.

Mr. Smith. Do your tests point in the direction that the smaller the amount of ash the better the coal is?

Mr. Barrus. Yes, generally that is true.

Mr. Smith. It seems to be that a practical test can be made by almost anyone weighing the coal on its way to the boiler, and then afterwards weighing the ash.

Mr. Barrus. That is a good practical test, but it is not abso-

lute. Now, take these same figures and reduce them to combustible. The figures on combustible with seventeen different samples of Cumberland coals, run from 15,300 down to 13,800. Hydrogen produces more heat in burning than carbon does, and as the proportion of hydrogen in the coal varies, that throws it all out. If it was all carbon and ash, then the heating value would vary with the percentage of ash. But with soft coals, the hydrogen varies, and that has a powerful influence on the calorific value. Anthracite coals, on the basis of combustible, vary, as I have the records here, from 14,500 down to 12,800. Here are four samples, from different parts of Illinois which, on the basis of combustible, run from 12,800 to 13,600, only five or six per cent. of difference, and yet on the basis of value, they run from 8,500 up to 12,700, about a third more; so that in that case the variation in ash would follow very closely the variation in the real value.

MR. NOYES. I trust that this line of investigation that Mr. Barrus has advanced, will be carried forward by our members, and I think practical results will be brought out which will be of great benefit to most, if not all, of our water works systems.

WATER SUPPLY OF LYNN.

BY

JOHN C. HASKELL, SUPT., LYNN, MASS.

[Read Sept. 11th, 1895.]

The water supply of the City of Lynn is furnished from the Saugus River and its tributaries. This river flows from Lake Quannapowitt, in Wakefield, through Lynnfield and Saugus, and forms a portion of the boundary line between Lynn and Saugus. The water from 22.91 square miles of its water-shed, flows by gravity to the pumping station.

The construction of our system of water supply was commenced in 1870. The first source of supply was from Breeds Pond, an artifical pond formed by a dam across the valley of Moore's brook, the nearest tributary of Saugus River to the city.

Breeds Pond when full has 22 feet of water at dam : contains 58.45 acres of water surface ; a storage capacity of 262,563,000 gallons ; a water shed including pond surface of 0.93 square miles. The dam was constructed upon an old dam. The original dam consisted of two nearly vertical walls of stone, the intervening space being filled with gravel. A portion of the front wall was taken down : the earth in front excavated to compact gravel. This excavation was filled with puddled earth forming a slope of 2 horizontal to 1 vertical and covered with riprap.

In 1878 the dam was raised and a stone coping put around the inside 2 feet high, set upon a solid foundation of masonry resting upon the original puddle wall. The main dam is 170 feet in length at crest; width of crest is 16 feet ; wet face with slope of 2 feet horizontal to 1 vertical, paved ; dry face solid masonry wall. There is a wing dam 100 feet in length at crest, 16 feet in width at crest, slope wet face 2 horizontal to 1 vertical, paved ; dry face $1\frac{1}{2}$ to 1. The spillway is situated at end of wing dam, is 25 feet in width, bottom and sides of heavy masonry. The waste water is allowed to

escape over paved steps and between masonry walls to the original brook below. When the pond was first taken the trees and bushes were cut off slightly above the flow line and all debris was burned; no effort has been made to remove the soil. We can add to its storage capacity by constructing a new dam immediately above the site of the present dam with 55 feet of water at dam; a pond surface of 175 acres and storage capacity of 1,628,000,000 gallons. It will also be necessary to construct a dam across a narrow valley on the west side of the pond; depth of water at dam 24 feet. This reservoir can be fully developed without encroaching upon land not owned by the city. In 1873 Birch Pond was added by constructing a dam across the valley of Beaver Brook, the second nearest tributary of Saugus River. Birch Pond when full has 21.50 feet of water at dam, a pond surface of 82 acres, a storage capacity of 381,062,000 gallons with a water shed including pond surface .66 square miles. The dam is founded on loose gravel; the centre is formed of clay puddle 5 feet in thickness; the earth embankment is formed of gravel. The main dam is 270 feet in length 20 feet in width on crest, wet slope 2 feet horizontal to 1 vertical, paved; dry slope 1½ feet horizontal to 1 vertical. The wing dam is 600 feet in length and constructed similar to the main dam. A granite coping 2 feet in height extends the entire length of the main slope. The overflow is at the end of the main dam 12 feet in width, excavated through ledge and lined with heavy masonry walls. The waste water escapes between masonry walls laid on a solid rock foundation to the valley below. No greater expense was incurred in preparing the bed of this pond than in Breeds Pond.

In 1883 Saugus River at Howletts mill was connected by a canal and tunnel with Birch Pond, Hawkes and Penny Brook. Tributaries of Saugus River were connected separately by canals with the main canal. A 30-inch pipe was laid under Birch Pond from the lower end of the canal to the gate-house permitting water to be used from the canal without connection with Birch Pond. In 1886 a pumping station was erected at the upper end of Birch Pond over the tunnel, equipped with a steam engine and boiler of 60-horse power; a Webber centrifugal pump capable of pumping 12,000,000 gallons of water daily from the canal into the pond. This became necessary in order to fill Breeds and Birch Ponds when they were unable to fill from their own water sheds. A connection be-

tween the pipe lines leading from Birch and Breeds Ponds to the pumping station was made.

In 1889 Walden Pond was formed by constructing a dam across the valley of Penny Brook, the third nearest tributary of Saugus River, and it was thought advisable to construct a second dam across an arm of Walden Pond to give increased depth to the upper end. This upper pond was named Glen Lewis. The two ponds, however, should be considered as one, no means having been provided to take the water of the upper pond without intermixture with the water of the lower pond. Walden Pond, when full, has 17 feet of water at dam; a pond surface of 128 acres, and a watershed, including pond surface, of 1.31 square miles; a storage capacity of 403,163,000 gallons.

In constructing Walden Pond dam, the soil, stumps and mud were removed from the entire foundation, requiring for several hundred feet a depth of from 14 to 18 feet. A trench four feet in width was dug through the centre until compact gravel was reached. This trench was filled with puddled clay which was carried up within two feet of the top. The earth embankment is formed of gravel. The length of the dam on crest is 1,275 feet; width of crest 16 feet; slope of wet face 2½ feet horizontal to 1 foot vertical, and paved 15 inches in thickness. Slope of dry face 2 feet to 1, of earth embankment, with 2 feet of soil on top. A spillway situated near the end of the dam, 80 feet in length, has a solid masonry wall in the centre and wing walls at the ends with heavy paving in its bed, to the valley below. We can also add to the storage capacity by constructing a new dam immediately below the site of the present one with 45 feet depth of water at the dam, a pond surface of 333 acres and storage capacity of 2,800,000,000 gallons. To utilize this reservoir it will be necessary to pump the water from Hawkes' Pond into the upper 27 feet. Water from this reservoir can be delivered into Breeds Pond by constructing a conduit of 1,300 feet in length and through a tunnel 2,700 feet in length.

Glen Lewis dam is 330 feet in length at crest and 40 feet in width, with a spillway situated at the end, 25 feet in width excavated through ledge and lined with masonry; the inside slope of earth three and one-half to one and covered with riprap. Outside slope masonry wall with batter 1 inch to 5 feet. Glen Lewis Pond when full has a depth of 17 feet, a pond surface of 36 acres, a water-

shed, including pond surface of 0.36 square miles, and a storage capacity of 120,475,000 gallons. No greater expense was incurred in preparing the bed of Walden and Glen Lewis ponds than in Breeds Pond.

In 1894 an area of 11.50 acres of the bed of Walden Pond was cleaned of all soil and organic matter. An arm of the pond containing 12.80 acres, where the water was shallow, was separated from the lower pond by a dam constructed with soil removed from the bed of the pond immediately below. A pipe provided with a gate was laid under the dam. This work was commenced with the intention of thoroughly cleaning out the entire bed of the pond, expending in this direction the surplus revenue each year that would otherwise revert into the sinking fund. An additional area will be cleaned this year.

Hawkes Brook Pond is now being added to the supply by constructing a dam across the valley of Hawkes Brook to the fourth tributary of the Saugus River. The pond, when full, will have a depth of 25 feet of water at dam; a pond surface of 75 acres; a watershed, including pond surface, of 1.92 square miles; storage capacity, 300,000,000 gallons; main dam at crest, 1,350 feet, width 20 feet, both slopes 2 feet horizontal to 1 foot vertical; inner slope a loose riprap of about 2 feet in thickness; outer slope and top of dam to be covered with loam. A core wall will extend from bottom to within 3 feet of top of embankment; from bottom of core wall to top of dam will be 55 feet; core wall is founded in solid ledge. There will be a wing dam 210 feet long at crest core wall and side slope same as main wall; water at dam 18 feet. Waste way will be at east end of dam 5 feet below crest and will be excavated through ledge to the valley below. All soil above the level at which water can waste from the pond is being removed. The gate-house will be so arranged that water can be drawn from any desired elevation. Through the main dam there will be one 36″ and one 30″ pipe.

The reservoir is partly on embankment and partly in excavation; the lines were regulated by the most favorable contours. The area, including embankment, is about nine acres. Its water surface is a little less than five acres and its depth is 18 feet. The capacity of the reservoir at 16 feet is 21,000,000 gallons. The bottom of the reservoir is covered with clay puddle 2 feet in depth.

The embankment is 16 feet on top; outside slope 1½ feet hori-

zontal to 1 vertical; inside slope 2 feet horizontal to 1 vertical. The inside slope is paved with heavy granite paving laid on riprap. One force main 30″ inches in diameter, one of 20″ and a distribution main of 16″ extend from the reservoir to the pumping station. A 12″ distribution main for the high service enters the reservoir at the northern side. The pumping station is divided into an engine room 50 by 56 feet, boiler room 40 by 46 feet, and coal room 41 by 46 feet. The well room is 50 feet in length, 10 feet 4 inches in width and 13 feet in depth. The walls of the well room are of granite lined with brick and covered with cement. The chimney is 120 feet high, octagonal in form and rests upon solid masonry 16 feet in depth. The site for the engine house contains about 70,000 square feet of land and has a frontage of 200 feet on Walnut street

The pumping plant consists of an engine designed by E. D. Leavitt of 5,000,000 gallons daily capacity and built by J. P. Morris of Philadelphia, and an engine which is known as a Loretz high-duty duplex compound beam and flywheel, consisting of two engines each of 5,000,000 capacity in 24 hours. This type has been adopted in preference to any single engine, for should any portion of the duplex gets out of order, the other remaining half can be disconnected and operated separately. The motive parts consist of four vertical cylinders arranged in tandem pairs of 18″ and 36″ in diameter and 5½ feet stroke. The two engines are connected together by large and heavy disc cranks set at right angles to each other on a massive shaft, having a 20-foot flywheel, the whole weighing about 20 tons. The entire weight of engine is about 250 tons, is nearly 50 feet in height from base of central columns to top of beams, and occupies a floor space about 24 by 36 feet. There are two galleries, the first being the operating gallery, where engine is started. There are four patent Loretz lift pumps operated from two beams, each being 22″ in diameter by 33″ stroke, and connected so as to force a continuous current through a 30″ diameter force tube without noise or jar. This engine was designed by Arthur J. Loretz of Brooklyn, N. Y. Both engines are doing very satisfactory work. The yearly duty for 1894 being: Leavitt, 106,996,048; Loretz, 103,176,674.

The boiler plant consists of two plain horizontal tubular boilers, each 5 feet diameter of shell, and containing 77 tubes of three

inches outside diameter, and 16 feet long, with a steam drum three feet in diameter, and 6 feet high. Also a Moore Water Tube, and Moore's boiler of 200 horse power capacity, containing 96 tubes, 4 inch outside diameter, 17.5 feet long, 2 steam drums, 3 feet diameter, 19 feet long, Grater 5′ by 7′, Economizer in flue, with 250 square feet heating surface; furnishing a duplicate set of boilers, either of which is equal to run our engines.

HIGH SERVICE.

Up to the present time our high service supply has been drawn from the same Reservoir as the low service, the additional pressure being gained by a separate pipe running direct from the Reservoir to the Highlands.

To secure better service on the Highlands, a stand pipe 50 feet in diameter and 35 feet in height, with a capacity of 500,000 gallons is being constructed on the summit of a hill near by the present Reservoir The additional pressure given will be 33 pounds. The foundation is based on solid ledge, and consists of a brick wall laid in Portland cement around the entire area; the inside area between the walls is filled with concrete composed of one part Portland cement, two parts sand, and five parts broken stone, varying in thickness from 2½ feet at the greatest depth to 8 inches at the least.

The pumping plant is located in the low service Pumping Station, and consists of two pumps attached to the Loretz engine, so arranged and constructed as to draw their supply, either from the pump well direct or force main, to a capacity of 1,500,000 gallons per day. Also to be connected on their delivery, so that they can deliver either to the high or low service reservoir, or both, at the same time. In this manner the capacity of the pumpage will be increased in the low service system as well, to the extent of three million, and the entire pumping system arranged to reduce the extra fuel consumption and maintenance to a minimum. There is also included an auxiliary pumping engine for a duplicate plant, so arranged as to either pump direct from the pump well, at the rate of one million gallons per day, into the high service or one and a half million into the low service.

FIRE PURPOSES.

The City of Lynn is exceptionally provided with a water supply for fire purposes. In the business portion of the city 1,000,000 gal-

lons per hour can be delivered if necessary, and not reduce the pressure below 45 pounds.

To show the purity of the water in our supply we present the following table, taken from the Report of the State Board of Health for 1890, page 532, which gives the number of deaths from Typhoid Fever per 10,000 of the living population from the same cause for the four years 1886–1889.

Lawrence 10.30, Lowell 9.55, Fall River 6.40, Holyoke 6.13, Chicopee 6.06, Haverhill 4.98, Boston 4.05, Cambridge 3.80, Worcester 3.11, Lynn 2.24, an average ratio of 5.43. The death rate in Lynn is the least of any and less than one-half of the average. From 1889 to 1893 the death rate of the City of Lynn from Typhoid Fever per 10,000 has been 1.73. In 1894 during which time we have been using the waters of Saugus River, the new supply, the death rate has been 1.38 per 10,000.

We also find from a table compiled from the census of 1890 showing the death rate from Typhoid Fever in cities in the United States with over 50,000 inhabitants that Lynn has the least death rate of any but one of the 54 cities, and equally as good as that, and but one-fourth of the general average. These figures show that we have nothing to fear from the quality of our water in this direction.

While it is not assumed that the periodical vegetable growths occurring in all surface water reservoirs are dangerous to health, the presence of large numbers of these organisms render the water disagreeable both in taste and odor.

To avoid as far as possible using water containing disagreeable organisms, samples are taken weekly from the surface and bottom of the different reservoirs and biological examinations are made and recorded. By watching the weekly growth of the different organisms, much valuable information in relation to our water supply is gained.

The time of the greatest growth of the organisms in each pond varies to such an extent that we have not been obliged to use the water of any source when the quality was the poorest. The growth to maturity and subsequent decay of some of these organisms is very rapid.

No organism liable to come from sewerage, or any injurious to health have been discovered. The value of these examinations is to

give a full knowledge of the condition of each specie of organism in each source of supply; the probable growth to be anticipated; the nature of each, whether injurious or harmless, and to gather all information possible as to the quality of the water before it is taken for use.

From our supply, as at present constructed, water can be drawn from five sources separately, or by twelve different combinations, from two or more sources.

It has been observed that the water containing some species of organisms improves in quality in its passage from the ponds to the city, while water containing other kinds deteriorates, it having been our experience that water with but slight taste, or odor perceptible in the ponds, became disagreeable when delivered for consumption. From this brief explanation the advantage of acquiring full information about the water in each source of supply can be seen.

DURATION OF SUPPLY.

Until 1894 a water-shed of 5.18 square miles has supplied all water needed. In 1894 water was first taken from Saugus River; this watershed comprises an addition of 17.73 square miles, making a total of 22.91 square miles, or more than four times our former area. Above Pranker's Mills, the point at which the canal connects with the river, 8.50 square miles has less than 50 population to a square mile, and will not be contaminated with sewage from any city or town. It can be provided with storage reservoirs sufficient to utilize the entire rainfall, as it becomes necessary to meet the increased comsumption, by raising the dams of our present reservoirs. No reason exists why this supply should not increase in purity as the reservoirs attain greater age, and properly developed, should furnish a pure supply for twenty years in the future.

FUTURE SUPPLY.

When the limit of supply from Saugus River is reached, our natural source of supply is the Ipswich River, which contains a water-shed of 34 square miles, situated at a sufficient elevation to flow directly into the pump well at our Pumping Station by gravity.

This water-shed is adjacent to the Saugus River water-shed. The water from an additional area situated below this point of 17 square

miles can be delivered into the Hawkes Brook valley at a comparatively slight expense and it is practicable to include a total of 96.70 square miles of the Ipswich River in our supply.

To still further enable you to judge of the quantity of water that can be provided for Lynn in the future, we will draw your attention to the total water-shed of the Ipswich River available, considered together with that of our present supply, as amounting to 119.60 square miles.

No charge is made for water used at fires, watering streets, drinking fountains, flushing sewers, public buildings, or for any city purposes. The works are self-sustaining, the yearly receipts being more than sufficient to meet the interest and maintenance.

DISCUSSION.

Mr. Noyes. As I understand, Mr. Haskell, you have had systematic and careful examinations of the water made from time to time by your special biologist, and you have also treated some portions of your reservoirs by covering them with gravel or sand. Have you from those examinations reached any conclusion with regard to the benefit derived from covering?

Mr. Haskell. In answer to Mr. Noyes, Mr. President, I will say that, as I briefly stated in the paper, we have commenced to clear out the bed of Walden Pond, and while I did not enter into it at all in detail in this paper I will, if circumstances permit, present another paper at a not distant date on what we have done in Walden Pond and what we have found out. I have made a very careful examination of the bed of the pond both before and after the work was done. We have recently run the water out of the pond, in connection with continuing our work in improving it, and I have had photographs taken which show very plainly the character of the work that we have done, and the dividing line between the work and the original soil. I have also had examinations made of the soil from the natural bed of the pond, and then from the gravelled portion, perhaps only three or four feet away; and the differences observed are very interesting.

Mr. Noyes. I think such information as that would be of great value to many of the water works officials who are making studies in that line. I have known of the work Mr. Haskell has undertaken, and hope we shall receive a paper from him. But I might

ask you to state briefly whether there is an appreciable improvement in the quality of water resulting from that work?

Mr. Haskell. We have had a very favorable year this year. In addition to cleaning out a portion of the bed of the pond, as late in the fall last year as we could, we burned the whole bottom of the pond over. We took kerosene oil and sprinkled it over the bottom, and we got a very hot fire. The small area that we separated from the pond, the 12.81 acres and the 11.50 acres that we cleaned, ought not to have made any very appreciable improvement, but the actual facts of the case this year are that while previous to this year we were not able to use the water of Walden Pond after the 23rd of May in any year, owing to the growth of algæ in it, this year we had absolutely no algæ in it whatever, while in our other ponds we had nearly the same amount of growth of algæ as formerly.

PUMPING STATION, MANCHESTER HIGH SERVICE.

A SHORT HISTORY OF THE MANCHESTER HIGH SERVICE

BY

Charles K. Walker. Supt., Manchester, N. H.

[Read Sept. 13th, 1895.

In his report of 1874, Mr. Fanning suggested that when a high service should be required, that an additional main, 24 inches in diameter, should be laid from the pumping station to the city. At that time there were but 9 or 10 houses too high to be supplied from the low service pipes, and they were supplied by water from good wells or springs in their neighborhood. The water for the low service is pumped by water power, and this plan contemplated pumping the high service supply in the same manner.

In 1880 the water in the lake, from which the supply is derived, became so low that it was necessary to deepen the channel, in order to get water enough to supply the city, and to furnish water power for pumping it. It was at this time that there was first serious talk in regard to the necessity of using steam at some future time to supplement the water power. After having deepened the channel at this time, the lake gave us water enough for 13 years, during which time the consumption increased from 1,200,000 to over 2,000,000 gallons per day, and as it requires seven gallons of water to pump one gallon furnished to the city, towards the end of that time it was not always possible to maintain sufficient pressure in the higher portions of the city, and the residents of those localities began to complain of the service.

The Commissioners had been considering the subject, and were of the opinion that it was best to have a high service, operated by steam, and so connected that it could also be used for pumping into the low service pipes, in case the water power became inadequate. The project, however, was opposed by a large part of the people,

and the daily press was unfavorable to it, You know very well that in order to get money for any improvement the public must be in favor of it.

A site for a high service reservoir was easily found in a range of hills on the east side of the city, but the route for the force main leading to it was not so easily selected, and the Commissioners concluded to employ a first-class engineer to look over the country and to make estimates, so that when the time came they would be prepared to recommend a suitable scheme. They secured the services of the late Marshall M. Tidd in 1890, to examine the different projects which had been suggested, and to make estimates for them. I will say that his estimates, so far as we have carried out his plans, have proved to be correct.

Mr. Tidd made estimates for three different pipe routes from the lake to the reservoir, and he also made estimates for taking the water from the low service and pumping it to the high service, but as this involved a double pumping, and would not in any way benefit the low service, it was abandoned.

It was suggested, as one of the schemes, to take water from Stephens' pond. This is a small pond entirely separate from Lake Massabesic, from which the main supply is obtained, and the water was said to be good by the chemist. My first doubt in regard to this source, was when a gentleman from Lynn, at one of our meetings some years ago said, "Never take a water from but one source of supply at once, for if you do there will be trouble, as each taker will wish he could have water from the other source." The question, however, was settled at once by Mr. Tidd, who said that he would not recommend water from that source.

A line was finally selected from Lake Massabesic, which we have every reason to believe was the best one. Both the pipe line and reservoir were constructed under the supervision of Mr. George E. Evans of Boston. The reservoir caused us a little anxiety, as it was built on a ledge full of seams, but it has never shown any signs of leaking; it will hold 4,000,000 gallons, and a full description of it is given in the report of Messrs. Rice and Evans, engineers. The water is pumped by two 3,000,000 gallon high duty engines, built by Henry R. Worthington. They were tested by Mr. Dean, who reported that they filled the contract. Pumping together they will supply 6,000,000 gallons into the low service, but will not do it into

the high service pipes. If the contract had read "both," instead of "each" where it says that "each pump should pump 3,000,000 gallons," perhaps it might have been different. The force main is 20 inches in diameter, and it is a little over 3½ miles long. The pumps work against 120 pounds pressure, or about 250 feet head. We have tried to operate both pumps at once, but this increases the pressure to 128 pounds, and we have not found it advantageous.

In conclusion I will say that we have got one of the best high service systems in the country, and the best part of it is, we got it in just in season to prevent a water famine.

The following description of the High Service is taken from the report of George S. Rice and George E. Evans, engineers above referred to.

SOURCE OF SUPPLY.

The pumping station is located on the west shore of the westerly part of Lake Massabesic and near the northerly end of the lake, and is a little less than two miles north of the outlet which supplies water to the low service pumping station. The intake pipe is cast-iron, twenty-four inches in diameter, and extends into the lake 255 feet from the shore wall. The end is covered with a heavy brass screen of three-quarter inch mesh, and is eight feet below the top of the dam. The elevation of top of dam is 147 feet.

PUMPING STATION.

The building consists of engine, boiler, and coal houses, all connected, and the walls are built of common bricks laid in red lime mortar, having granite underpinning, window and door sills.

The underpinning is laid in horizontal courses and the height varies from four to five and one-half feet. The roofs over the engine and coal houses are supported by wooden trusses and covered with slate. The roof over the boiler house is flat and constructed of large southern pine beams and two-inch spruce plank covered with tarred paper and gravel. The flat portion of the engine house also has a graveled roof. The cornices are made of galvanized iron,

and the finials, hip and ridge rolls are copper. The engine room floor is made of two-inch spruce plank covered with southern pine one and one-fourth inches thick.

The floor in the boiler room is tar concrete and brick, and in the coal room is tar concrete. The elevation of the engine house floor is 158.5 feet and the boiler room floor is two feet and eight inches lower. The chimney is circular in plan and 100 feet and 9 inches in height above the foundation, and built of common bricks laid in red lime mortar, with an addition of about one-third cement. The first seven feet were laid in cement mortar.

The base of the chimney is eleven feet in diameter and at the smaller section near the top it is seven feet three inches in diameter. The cap is cast-iron, made in eight sections and bolted together with composition bolts, and weighs three and four-tenths tons.

The chimney has an inner shaft four feet inside diameter which extends to the top, and the smoke flue enters the chimney eighteen feet above the boiler room floor. The foundation is nineteen feet square and starts on a layer of compact gravel seven feet below the surface of the ground. There is an opening at the base of the chimney for taking out the soot.

The pump well is located at the east side of the engine room cellar and the east wall is also a portion of the engine house foundation. The well is ten feet eight inches wide by twenty-one feet eight inches long, and the elevation of the bottom is 136.5 feet. The sides are built of cement rubble masonry, and the inside of the well is lined with bricks four and eight inches in thickness, and the bottom is cement concrete and bricks, and is water tight. The screen chamber is located at the southeast corner of the well, and there are two sets of copper wire screens of one-fourth inch mesh. At the end of the 24-inch intake pipe there is a sluice gate to shut off the water from the well when necessary. Scales have been built into the floor of the boiler house for weighing all the coal used in the boilers.

At the rear of the pumping station a retaining wall 178 feet in length has been built of dry rubble along the lake and the grounds graded and sown with grass seed.

During the fall a dwelling house and stable have been built near the pumping station for the use of the engineer.

ENGINES AND BOILERS.

The bottom of the foundation for the engines is built of granite about one foot thick, and the upper part of the foundations is built of bricks laid in cement mortar, excepting the top, which is finished with fine cut granite.

There are two Worthington high duty pumping engines, each having two high pressure cylinders 30 inches in diameter, and two double-acting water plungers 15¼ inches in diameter. The engines will deliver 51.62 gallons per revolution when making the stipulated stroke of 18 inches, after making a deduction of 5 per cent. for slip. Each engine was guaranteed to deliver into the reservoir 3,000,000 gallons in twenty-four hours against a dynamic head of 254 feet. The static head is about 250 feet.

FORCE MAIN.

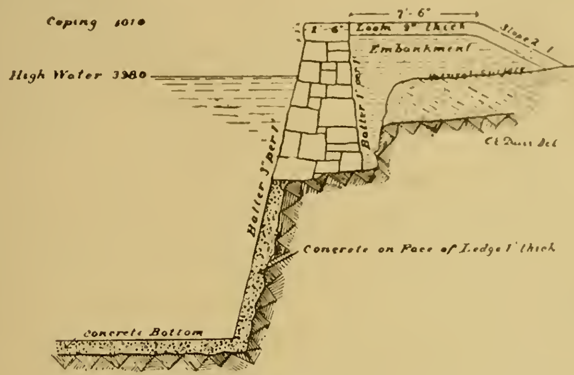
The force main is cast-iron and 20 inches in diameter and was laid during the fall of 1893, excepting a short piece at the reservoir which is 24 inches in diameter. There are two classes of pipe: Class B varies in weight from 2,400 to 2,464 pounds, and class A from 1,980 to 2,080 pounds per lengths of 12.46 feet.

There are 7 gates, 13 hydrants, 6 air-valves, 2 10-inch and 5 6-inch blow-offs located along the force main. From the engine room cellar to the gate chamber at the reservoir there are 19,076 feet of 20-inch and 80 feet of 24-inch pipe, making a total distance of 3.63 miles.

RESERVOIR.

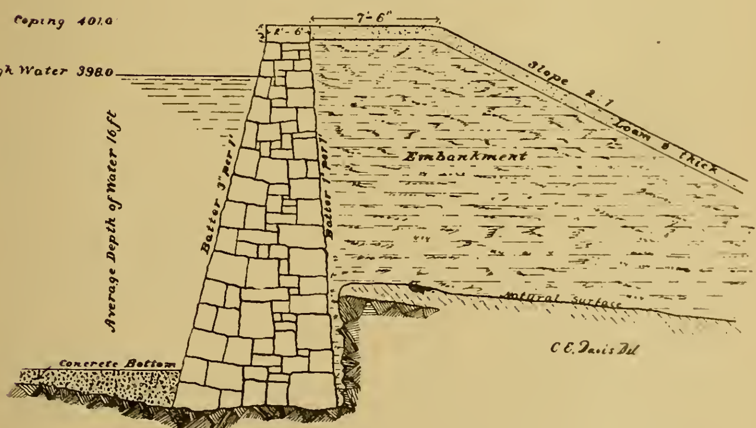
Many depressions in the bottom were filled to subgrade with the best puddling material found on the work, which was thoroughly wetted and afterwards made compact by constant teaming over the bottom. There were several fissures in the ledge along the south side which were filled with cement grout. The bottom is covered with cement concrete, having an average thickness of ten inches, including a layer of cement mortar about three-fourths of an inch thick. The face of the ledge on the north, east, and west sides is covered with concrete to the top, which varies in thickness from six inches to three feet, and the average thickness is about one foot. The excavation did not furnish suitable stone for the face of the wall. The face stone and coping came from Bodwell's quarry and the back of the wall came from the excavation. The wall is laid in

cement mortar having a batter on the face of three inches to the foot, and is thirty inches wide at the top under the coping. The coping is the full width of the wall, one foot thick, and the end joints are filled with Portland cement.



Section of Combined Ledge & Masonry Wall at AB

Scale of Sections ¼ inch = 1 foot



Section of Masonry Wall at CD

SECTIONS OF EMBANKMENT, HIGH SERVICE RESERVOIR.

All the corners of the reservoir are circular in shape excepting the one at the southeast, which is cut off at an angle of forty-five

degrees, so as to form the front wall of the gate chamber and to give more embankment, thus strengthening the reservoir at this place.

The bottom of the reservoir is not a uniform plane, as the surface was governed largely by the way in which the excavation could be made. The wall at the northeast corner is nineteen feet, and at the southwest corner twenty-two feet high.

The bottom has a slope towards the drainpipe at the gate chamber, excepting a small portion at the southwest corner, which is nearly two feet below the drainpipe. At this place the rock was very rotten, being mostly composed of mica, and it was considered advisable to take out this objectionable material even if there was a small portion below the grade originally intended. To have filled it to grade with concrete would have incurred quite a large expense without giving sufficient benefit, but the depression will form a place for the deposit of mud, which is desirable.

Six springs were found along the north side, and three near the southwest corner. Small iron pipes were built into the masonry at these places. At the time the reservoir was filled only two were draining a very small quantity of water into the reservoir. The top of the embankment is 10 feet wide, including the masonry, and has an outward slope of two to one, and was made in horizontal layers of the excavated earth, thoroughly wetted and made solid by constantly teaming over it and by ramming the portions nearest the wall. The outside was covered with loam found on the work and sown with rye and grass seed. The elevation of the top of the embankment is 401 feet and high water is 3 feet lower.

The inside of the gate chamber is 15 feet wide by 15 feet 6 inches long and 20 feet deep. It is divided into two compartments, one for the weir and the other for the screens. There are four 20-inch sluice gates; two of them are located 8 feet apart vertically, so that water can be drawn from two levels. When the reservoir is full it would be better to draw through the upper gate, for should an accident happen to the force main, there would be less liability of a large quantity of water being drawn of. A permanent weir of southern pine, having its edges of steel, is built into the masonry. The elevation of the crest is 397.29 feet.

METHOD OF BUILDING CONCRETE WALL, HIGH SERVICE RESERVOIR.

CONCRETE ON SIDES AND BOTTOM, HIGH SERVICE RESERVOIR.

GATE HOUSE.

The exterior walls are composed of stone having quarry faces, which came from the reservoir excavation, care being taken to select those having the most color, and the trimmings are granite from Bodwell's quarry. The interior walls were built of the best face-brick laid in red lime and cement mortar.

The floor is supported by brick arches, and the top will be covered with Portland cement mortar.

The ceiling is Georgia pine, nailed to the rafters, and will have two coats of hard oil finish.

The gate house is nineteen feet ten inches square, and has a hip roof covered with red slates and terra cotta hip rolls.

OBITUARY.

JOHN L. HARRINGTON.—Superintendent of Water Works, Cambridge, Mass., member of the Finance Committee of this Association. Died August 16th, 1895, aged 39 years and 3 months. Joined this Association June 15th, 1887.

Mr. Harrington was employed in the office of the City Engineer of Cambridge for several years, where his efficient service led to his appointment as inspector in the water department. From this position he was promoted to foreman, and he succeeded to the office of Superintendent in 1894.

Mr. Harrington was very systematic in his work and managed the affairs of his department with great ability and his strong character and unwavering honesty won him many friends.

MARSHALL M. TIDD.—Civil Engineer. Died Aug. 20th, 1895, aged 68 years, 19 days. Joined this Association June 18th, 1885.

Mr. Tidd was a native and resident of Woburn, Mass. At the age of 19 he entered the employ of Mr. Storrow at Lawrence, Mass., and later opened an office in Boston where he has been located for the past 45 years. As an expert hydraulic engineer Mr. Tidd was well known, having served as consulting or constructing engineer for more than 50 different systems of water works as also for many systems of sewerage and dry docks. He was a member of the Boston Society of Civil Engineers and the American Society of Civil Engineers, and was at one time Water Commissioner for his native city. He took an active interest and was a frequent participant in the discussions at our meetings and was well known and respected by all our members.

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NEW ENGLAND WATER WORKS ASSOCIATION.

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UNIFORMITY OF METHODS IN TESTING WATER METERS.

BY

JOHN THOMSON, M. AM. SOC., C. E., NEW YORK.

[Read Sept. 11th, 1895.]

The increasing use of water-meters, and the rapidly growing sentiment in favor of their application, is leading to the more general testing of meters by water works officials; as also to more exacting requirements respecting their performance, and especially is this the case regarding the low-rate registration of the smaller sizes of meters used in domestic service. This observation at once leads to the query: Is it not time that more uniform methods of testing be adopted by the purchasers of meters; especially in the smaller calibres for domestic use?

It is believed that the question answers itself affirmatively; but among the reasons leading to this conclusion it may not be amiss to mention that, as between the purchaser and the manufacturer, the advantage would be mutual; the single illustration sufficing that the conditions are here almost identical with that of uniform standards in pipe-threads and flanges.

The corollary, then, is query number two. In what particulars of meter-testing should uniformity of methods be attempted?

Here, undoubtedly, there is room for many opinions, and it is hoped that the discussion evolved may lead to a codification of present rules and practices. The writer selects the following features, which to him appear as most deserving of consideration and adoption, namely: first, should not the rating of meters, especially in low flow tests, be by timing the deliveries of definite quantities, rather than by designating the diameter of jets; second, what shall be the limit of the minimum rate; third, what shall be the limit of the maximum rate; fourth, should tests be referred to the meter or the tank; fifth, should the error be indicated in pounds or percentage.

LOW FLOWS SHOULD BE DESIGNATED BY TIME-RATING.

As to the first, namely: the method of rating at low flows, the writer is strongly of the opinion that the time-rate should be adopted, as being correct in theory and thoroughly demonstrated by long practice, especially so in Europe. The amount of uncertainty regarding this subject can probably be best attested by the vendors of water-meters, to whom the most widespread experiences converge. Thus, the inquiry may be from one, "how accurate will your meter work," with no mention of pressure, conditions, range or rate; from another, "meter must test down to a fine stream," and when this is defined you may receive the specification, "on a stream as small as a darning needle," the pressure being, say, 30 lbs.; or from another, "on a stream about as big as a pipestem," and the pressure in the latter case may be 100 lbs. Then, too, where the practice has advanced to the employment of perforated diaphragms, it is rather the exception than the rule for purchasers to make note as to the form of the perforation or the pressure behind it. And, moreover, as between the aggregation of thin brass, punched; copper pennies, drilled; lead diaphragms pierced by an awl, and the eminent expert who laid the fault of a certain test to the fact that a perforation alleged to be $\frac{1}{32}$ inch dia., was found to be 0.0075 inch too large, there might yet be added such cases as where the decimal 0.0625 inch was read $\frac{1}{90}$ inch, with results as entirely satisfactory to the manufacturer, as in the instance of a certain wasteful child of Neptune, who said, "Fix my meters to measure by the barrel, when I want to sell water by the drop I'll order a Homeopathic vial and a quill!"

Now, let it be said, that in testing a meter at low flows, the only point desired to be known is, what quantity in pounds, gallons or cubic feet is passing in a minute or an hour; the sensibility of the meter is alone established by this; if one meter, to operate accurately, requires a draught of 2 cubic feet uniformly drawn in one hour; and another meter operates with equal accuracy upon a draught of 1 cubic foot in the same time, then the latter has twice the sensibility of the former. The only function, then, of a throttling diaphragm is to determine the rate of flow, and the only method of ascertaining this is to carefully rate the perforation by measuring its discharge under a definite pressure for a definite period of time. If time-honored truths will bear repeating, then so will hydraulic principles; which alone is the excuse for here presenting a few illustrations, with the view of impressing upon the memory the importance of following the procedure just recommended.

Fig. 1.

Fig. 2.

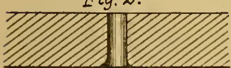
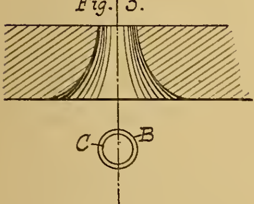


Fig. 3.



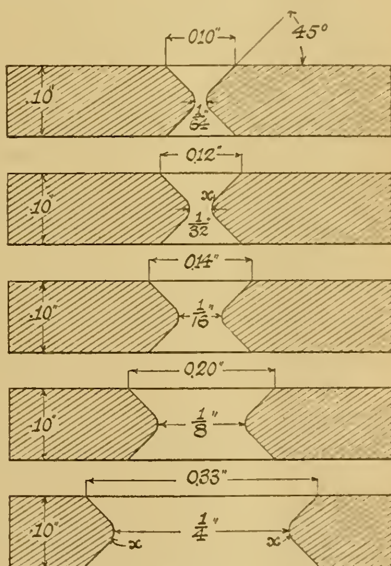


Fig. 4.

Thus, in Fig. 1 is represented, to a large scale, a diaphragm, the original of which is $\frac{1}{32}$ inch thick; the perforation being precisely $\frac{1}{32}$ inch diameter, with the edges knife-sharp. The delivery of this orifice under a pressure of 50 lbs. to the square inch is approximately 1 cubic foot an hour. In Fig. 2 a diaphragm is represented

to the same scale as Fig. 1, the original of which is $\frac{3}{32}$ inch thick, having precisely the same diameter of orifice and the same knife-sharp edge on the upper side, but with the lower edge very slightly rounded by lightly scraping the edge with a sharp knife. The delivery of this diaphragm, under the same pressure as the former, with the upper sharp edge to the flow, is nearly 1.12 cubic feet an hour. Hence the difference in thickness alone gives the thin diaphragm, at the pressure named, 12 per cent. *less* delivering capacity than the thicker one. Again, with this diaphragm reversed, the slightly rounded edge to the flow, the delivery is nearly 1.50 cubic feet an hour, or 33 per cent. greater delivering capacity than from the sharp edge. These are to show how apparently trivial differences may greatly affect the comparison of results. Again, referring to Fig. 3, a diaphragm is represented in the original, of which the perforation is precisely $\frac{1}{16}$ inch diameter, the thickness $\frac{1}{8}$ inch, one edge knife-sharp and the other very nicely rounded to a curve of about $\frac{1}{8}$ inch radius. This diaphragm, under a pressure of 50 lbs., each side being separately presented towards the pressure, gave the following result: With the upper sharp edge to the inlet, the delivery was about 5.30 cubic feet an hour; reversed, with the lower rounded edge to the flow, the delivery was about 7.10 cubic feet an hour, or nearly 34 per cent. greater than the first. The well-known reason for this difference in delivering capacity is indicated in the circles C, B; the inner circle, C, denoting the area of the contracted jet, from the sharp edge, while the outer circle, B, denotes the stream from the rounded side equal to that of the area of the orifice.

The practical application of this to the present subject is as follows: Suppose two meters equally accurate at 7 feet an hour and equally inaccurate at 5 feet an hour. Then, furthermore, suppose that two water works are supplied with these meters, requiring them accurate, according to their specification, on a jet $\frac{1}{16}$ inch dia. at 50 lbs. pressure, and that it so happens that one of these works is provided with a diaphragm, sharp, as the upper side of Fig. 3, and the other works, with a rounded perforation, as the low side of said figure. Obviously, the works using the sharp-edged diaphragm will find the meter defective, whilst the other will be accepted as correct. Evidently, had these meters been ordered to be correct at a minimum rate of 5 cubic feet an hour, and had

then been tested respectively under conditions to obtain this rate of flow, each purchaser would have been equally suited, and the cup of human happiness would have been nearer to the full.

As a means tending to reach the result here aimed at, it is suggested that a standard form of perforation be adopted in the diaphragms used in testing water-meters, and it is believed that the forms shown in Fig. 4, when taken with the simple method of their construction, would come well within the practical requirements of such service. In the several parts of the aforesaid figure which are drawn to a considerably enlarged scale, five diaphragms are shown, the diameters, at the throat-sections of the perforations, being those already most generally employed, namely: $\frac{1}{64}$, $\frac{1}{32}$, $\frac{1}{16}$, $\frac{1}{8}$ and $\frac{1}{4}$ inch respectively.

To most conveniently accomplish the end here sought, it is essential that the several diaphragms of a series shall be of uniform thickness, and No. 10 American gauge, or approximately 0.10 inch, has been selected; the metal to be of hard rolled brass. The production of any one of the perforations is as follows: first pierce with a drill one size smaller than the desired gauge; second, with an accurately ground counter-bore, of 45° angle, counter-sink each side of the metal disk until the large diameter on the face, as noted in the drawing, shall be reached; third, the throat is then to be brought to exact diameter by reamer and round brooch, and, finally, the sharp knife-edge portions at the intersections of the throat with the cones, as at X, are to be lightly polished out by using a pointed stick with pumice stone. The object of sinking the counter-bore to produce a definite diameter at the face, is to establish the depth of the cone; and these face dimensions are such as to produce a uniform thickness and contour at the throat in all of the sizes. The advantages of making both sides alike, and of counter-boring, are that either side may be presented towards the inlet, and that the throat is protected from injury.

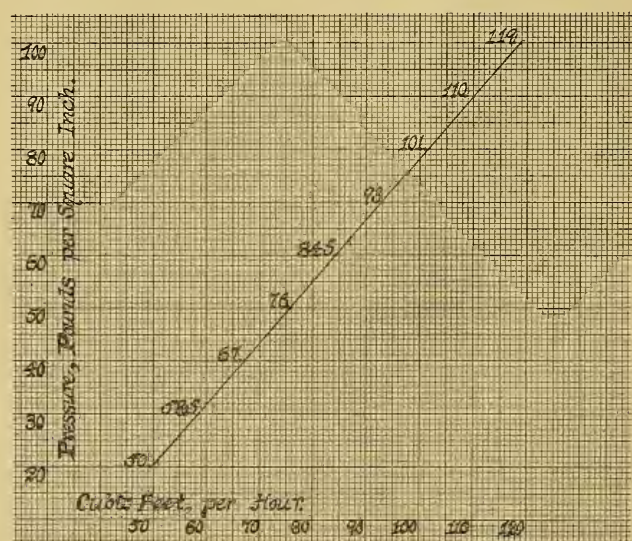
If both the purchasers and the manufacturers of water-meters would conclude to accept even this mild departure from existing practice, there would be a distinct gain to the good. And to those who may care to take up this practice, of referring comparative tests to a time basis, the following time-rate testing table is presented, approximately indicating the hourly deliveries which may be expected, in terms of cubic feet, when the diaphragms herein

described are employed, and when the dynamic, or "running," pressure named is maintained at the diaphragm.

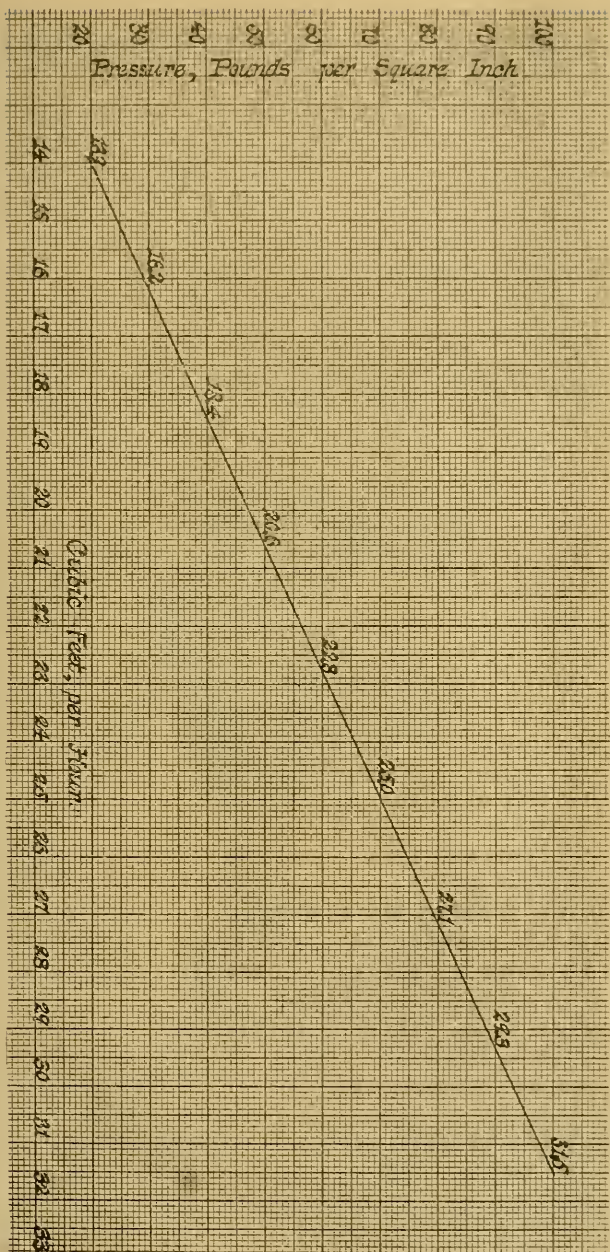
WATER METER BENCH-TESTING TABLE, GIVING APPROXIMATE RATES OF DELIVERY IN CUBIC FEET PER HOUR OF NEAREST EVEN QUANTITY THROUGH PERFORATIONS FORMED AS SHOWN IN FIGURE 4.

Pressure. Pounds.	Diameter. Inches. 1-64	1-32	1-16	⅛	¼
20		0.75	4.00	14	50
30				16	58
40		1.00	5.25	18	67
50	0.50			20	76
60		1.25	6.50	23	84
70				25	93
80			7.50	27	101
90				29	110
100	0.75	1.50	8.50	31	119

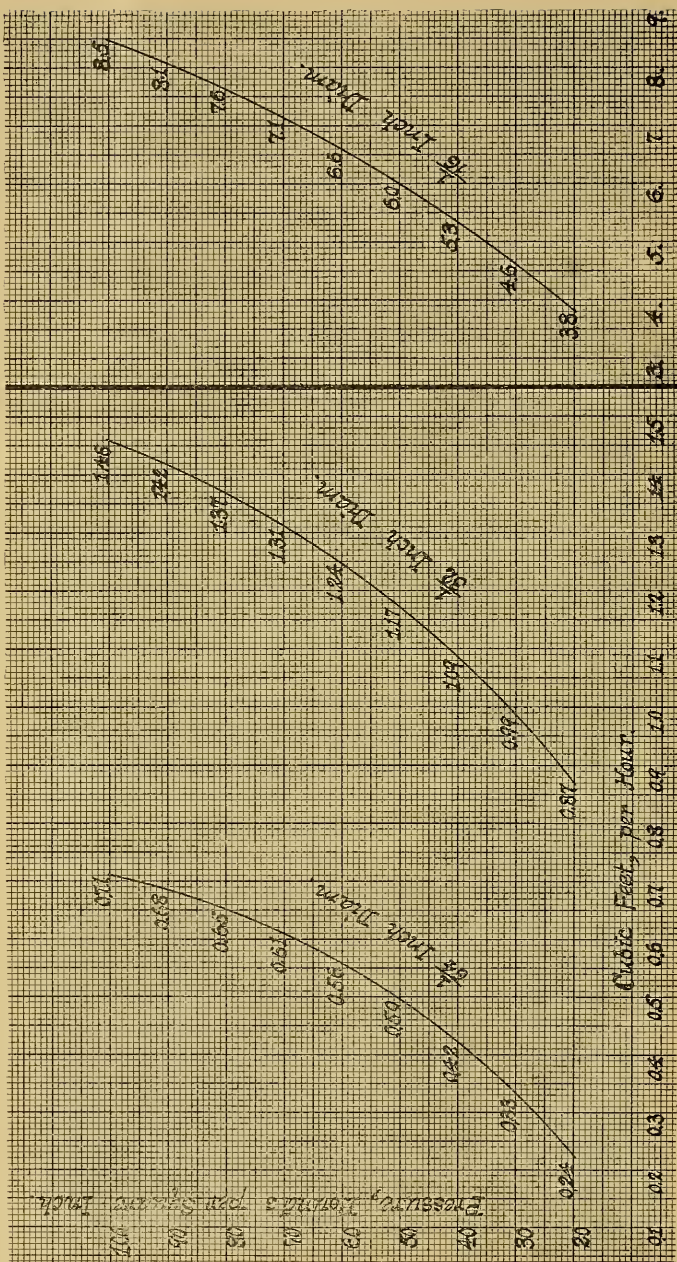
NOTE.—It was originally contemplated to prepare this table to show approximately exact deliveries for pressure increments of 5 lbs.: but after having prepared such a tabulation, it appeared to the writer, that a wider range in pressures quantities averaged to even amounts would inadequately meet the requirements of regular service. Moreover, it is thought that the table, because of the increased simplicity and brevity, will be more likely to be utilized by practical men. Where deliveries at intermediate pressures are desired, they may be ascertained from the following diagrams :



APPROXIMATE DELIVERY THROUGH ¼″ ORIFICE FORMED AS SHOWN IN FIG. 4.



Approximate Delivery Through $\frac{1}{8}''$ Orifice Formed as Shown in Fig. 4.



Approximate Deliveries Through $\frac{1}{64}''$, $\frac{1}{32}''$ and $\frac{1}{16}''$ Orifices Formed as Shown in Fig. 4.

In carrying out these determinations of jet deliveries through the definite forms of perforation illustrated in Fig. 4, the water was weighed. A pair of Aschcroft test-gauges were used, these being specially compared and furnished under order to be graduated from a mercury column. The pressures were obtained by a Worthington pump and a Fisher regulator, both of which were specially overhauled and refitted for the purpose of obtaining this data. The pressure, as indicated by the gauge, was maintained with satisfactory steadiness. Any refinement of scientific accuracy, however, "the triumph of the last place of decimals," is expressly disclaimed, but judging from the uniformity of indications under repeated experiments, it is believed that the results from which this table was prepared are well within the practical requirements of the intended service. (In this connection, see foot-note on table, page 82.)

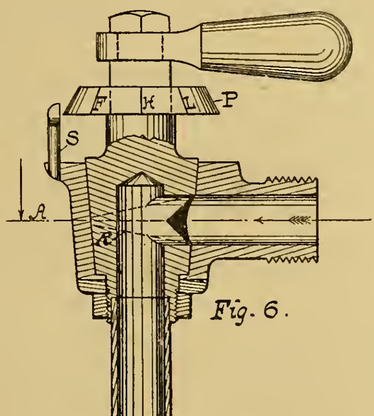
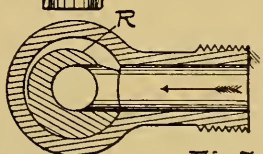


Fig. 6.



Section on A *Fig. 7.*

In Figs. 6 and 7 two sectional details are shown of a graduated valve for testing water-meters by time-rating, as used by the writer's company, which so far has proven quite satisfactory in practice. This device consists of a simple plug-valve adapted to receive the flow at the side and discharge from a tube inserted in

the end of the plug; about half the circumference of the side of the plug being recessed to the form of a V, gradually diminishing both in depth and width from the main inlet until vanishing in the surface, as denoted by the letter R, in the drawings. Applied to the upper extension of the plug is a dial-plate, P, and inserted into the face of the casing is a sight-pin, S. Obviously, by simply turning the plug so that different portions of the circular V-groove is presented to the inlet, the area of discharge may be very uniformly increased or decreased between the entire range of the scale. Then, by timing the delivery, any desired series or combination of tests may be made. In our practice the letter F is stamped on the graduate to indicate full flow, H for half; L for low and S for sensibility, these, under 60 lbs. pressure, giving approximate rates of 90, 40, 15 and 1.5 cubic feet an hour. Where many meters are to be tested at different rates, this device effects a considerable saving in time over that required in the changing of diaphragms.

THE LIMIT OF THE MINIMUM RATE.

As to the second query. What minimum rate should be insisted upon in water-meters, to be used in domestic service, the writer holds the opinion that this should be adapted to the conditions of the service. But the following general recommendation is ventured: When the water is reasonably pure and free from grit, it is believed to be well within the power of manufacturers to regularly supply the smaller sizes of positive rotary and piston meters to indicate within 3 per cent. of accuracy at the rate of 1 cubic foot uniformly drawn in one hour. And a meter which will do this may generally be depended upon to indicate, though not necessarily with much accuracy, down to from $\frac{3}{4}$ to $\frac{1}{2}$ a cubic foot an hour. But the insistence upon such a degree of sensibility, except only where the water is free from grit, may invariably be taken as indicative of anything except good engineering sense. In this connection, however, it is not to be overlooked that the employment of meters and the reduction of waste tends, to the betterment of a water supply.

AS TO THE MAXIMUM RATE.

And now as to the third query of the opening. What should be the limit in testing a meter to maximum operation? The answer to this, if taken from general practice, is easy, namely: all that can

be blown through. The writer has known of many cases where the only tests for accuracy in meters of the $\frac{5}{8}$-inch size were at the rate of from 3 to 4 cubic feet a minute, that is from 300 to 400 per cent. in excess of usual practical requirements. In a test to demonstrate the durability, or the extreme power and capacity of a meter, such a trial may be eminently proper; but there appears to be but little warrant for such a practice as a check for accuracy. However, opinions differ widely on this point, notwithstanding that there appears to be an entirely satisfactory basis for such tests, even though empirical, namely: the highest maximum delivery likely to be drawn through regular service pipe. A bench test to check performance under such conditions is obviously of value; from this down to the minimum rate is the field of the performance of the meter. It would seem that the extreme velocity in the commercial sizes of $\frac{1}{2}$, $\frac{3}{4}$ and 1 inch service pipe of, say, 15 lineal feet a second, is about as high as good practice would warrant. As a matter of fact, such a velocity is not common, but even this extreme rate would only discharge nearly 1.8, 2.8 and 4.8 cubic feet respectively; hence a bench-test for accuracy at maximum rate probably need rarely exceed, say, 2 cubic feet a minute for a $\frac{1}{2}$ or $\frac{5}{8}$-inch meter; 3.5 feet for the $\frac{3}{4}$-inch meter, and 6 feet for the 1 inch.

IN LOW RATE FLOWS SHOULD THE METER BE THROTTLED AT THE INLET OR THE OUTLET.

The inquiry is occasionally made if, in testing a meter under low flows, it makes any difference in the results as to whether the meter be throttled at the inlet or the outlet thereof. Generally speaking, it is more favorable to the meter to throttle at the inlet, leaving the outlet fully open, as it is thus relieved of all strain except that of the back-pressure of the outlet pipe. If meter-devices were in theoretically perfect equilibrium, under pressure, there would be no difference; but, within the knowledge of the writer, there is no such mechanism. Consequently, if it were desired to obtain registration at the very lowest rates of flow, it would be advantageous, if the conditions would permit, to throttle at the inlet, leaving the outlet free; but it is essential in such cases that the pipe leading from the outlet side of the meter shall be so arranged as to keep the meter full of water, that is under a minimum of

back-pressure. This admonition is offered for the reason that the writer has heard of a number of cases in which this precaution was neglected; in consequence of which the meters were operated with their upper chambers empty. And although in the instance of models adapted to kindergarten exhibits, this vacuous condition has been advantageously utilized (as even betimes by the conscientious meter-maker), it is not to be recommended for regular practice. But in all regular bench-tests the meter should be throttled at the outlet when tried for sensibility; as this is the condition under which the device must regularly operate.

A FEW PRIMARY RULES TO BE OBSERVED IN BENCH-TESTING.

Water should be turned on to an empty meter slowly, until completely filled.

It is preferable to run a small quantity through a meter before starting a test.

In all meters it is desirable to eject the air before testing. The most ready and efficient means to this end, when vent screws are not provided, is to turn the meter over a few times, when connected for the test, on its side, or upside down, in which position it should be operated to drive out the air displaced by the change of position. This precaution is usually not worth observing when setting the meter in regular circuit; as the entrained air will gradually be absorbed and ejected.

In testing by weight, when using a tank mounted upon a platform scale, if especially accurate results are desired, it is well to read the scale-lever as it swings to some arbitrarily fixed mark near its end; the reason for this being that the majority of such scales are "logy" when loaded, and can often be read from one to three pounds in error.

In testing by tanks, provided with glass tubes, there is a source of error due to capillarity; the extent of which varies somewhat with the condition of the atmosphere and the observer and the degree of cleanliness of the inner surface of the tube. Thus with a clean surface and pure water, the end-surface of the column will be concave, due to the attraction of the glass; whereas, if the surface of the glass is greasy, this will act to repel the water and the end-surface of the column will be convex. On the whole, it is well to

swab out such tubes occasionally, and a little alcohol on the swab will not hurt the job. In view of these conditions, it is generally believed to be the most uniformly reliable procedure to read the height of the column from the center thereof, be it concave or convex. And this is an argument in favor of glass tubes of large diameter.

Where the most exacting results are desired from a meter in low flow performance, the pressure should be maintained as nearly uniform as possible. If the pressure varies considerably, this may result either favorable or unfavorable, either to the maker or the purchaser. The reason for this is that a pulsating pressure, during sensibility flows, may produce different effects upon different meters.

When using the $\frac{1}{64}$ inch or the $\frac{1}{32}$ inch diaphragms, especially if the test is to be of long duration, it is well to insert a piece of sponge to prevent particles of grit from closing the perforation.

In all positive meters having hard rubber displacing members, more accurate results may be expected, at low rate performance, when the water used for the test is rather tepid than cold; the reason for this being that the normal co-efficient of expansion and contraction of hard rubber is greater than that of brass or composition. This fact is taken into consideration, occasionally, in the construction of meters. It is for this reason that a meter will often fail to operate freely by blowing when taken from a shelf in a warm room, but will be all right when cooled in water.

A meter which operates correctly at the higher and lower rates of flow and fails on the sensibility trial, may often be corrected by simply reversing the meter and running it backward for a few minutes; as, if the cause of the difficulty was a slight foreign obstruction, this treatment will often remove it.

In a water meter, to ascertain its obstruction to the delivery, relative to the service pipe, proceed as follows: First, insert a piece of regular service pipe of the same nominal size and the same length as the meter, placing it in the same position and using the same couplings and packing-washers as are used when testing the meter. Second, apply a diaphragm to the outlet, as in regular testing, whose diameter is somewhat less than that of the bore of the spuds of the meter. Third, then make a number of runs, each of exactly the same amount, and carefully record the time of each

run. Thus, if you have made four runs of 10 cubic feet each and the time of each flow is 2½ minutes, you will have an aggregate of 40 feet divided by 10 minutes equalling 4 cubic feet a minute, the capacity of the pipe. Now, insert the meter (or the several meters, successively, if the test is to be comparative of kinds) in place of the piece of pipe, again being careful to use the same connections, and packing-washers as in the instance of the pipe. Then proceed as before, and run the same quantity for the same number of tests and carefully record the time required for the delivery of each. Should you have an aggregate of 40 feet delivered in 12 minutes, in the case of one meter, then its relation to the pipe would be 10 divided by 12, that is the meter would have a capacity equal to 83.3 per cent. of that of the pipe. If another meter should require 13 minutes, its capacity relative to the pipe would be 76.9 per cent. and the first meter would have 8.3 per cent. greater capacity than that of the second. $(\overline{83.3-76.9}\div76.9=8.3$ per cent.)

In bench-tests, the usual trial runs are as follows: One, two, five and ten cubic feet, the correct weight equalling, respectively, 62½, 125, 312½ and 625 lbs. Sensibility tests, because of the time required, are frequently made by tenths of a foot, each tenth being equal to 6¼ lbs., or approximately 3 quarts. In connection with the foregoing, the following percentage table may be of service:

PERCENTAGE TABLE FOR BENCH-TESTING OF WATER METERS.

1 Cubic Foot=62.5 lbs.

Actual Indication of Meter in percent.	Error in percent.	Cubic Feet Indicated by Meter to Pounds of Water Found in Tank.			
		1.	2.	5.	10.
	Over				
104.1	4.1	60.0	120.0	300.0	600.0
103.3	3.3	60.5	121.0	302.5	605.0
102.4	2.4	61.0	122.0	305.0	610.0
101.6	1.6	61.5	123.0	307.5	615.0
100.8	0.8	62.0	124.0	310.0	620.0
100.0	0.0	62.5	125.0	312.5	625.0
	Under				
99.2	0.8	63.0	126.0	315.0	630.0
98.4	1.6	63.5	127.0	317.5	635.0
97.6	2.4	64.0	128.0	320.0	640.0
96.9	3.1	64.5	129.0	322.5	645.0
96.1	3.9	65.0	130.0	325.0	650.0

PERCENTAGE AND TIME-RATE TABLE FOR FRACTIONAL SENSIBILITY OR "LEAKAGE" TESTS.

Actual Indication of Meter in Percent.	Error in Percent.	One Tenth Cubic Foot Indicated by Meter to Pounds of Water in Tank.
	Over	
108.6	8.6	5.75
104.1	4.1	6.00
100.0	0.0	6.25
	Under	
96 1	3.9	6.50
92.5	7.5	6.75
89.2	10.8	7.00
86.2	13.8	7.25
83.3	16.7	7.50
80.6	19.4	7.75
78.1	21.9	8.00
75.7	24.3	8.25
73.5	26.5	8.50
71.4	28.6	8.75
69.4	30.6	9.00
67.5	32.5	9.25
65.6	34.4	9.50
64.1	35.9	9.75
62.5	37.5	10.00

One-tenth Indication in 3 minutes equals a rate of 2 cubic feet an hour; in 3m. 30s. = 1.7; in 4m. = 1.5; in 4m. 30s. = 1.3; in 5m. = 1.2; in 5m. 30s. = 1.1; in 6m. = 1.; in 6m. 30s. = 0.92; in 7m. = 0.85; in 8 m. = 0.75; in 9m. = 0.66; in 10m. = 0.60; in 11m. = 0.55; and in 12m. = 0.50.

IN BENCH-TESTING, WHICH SHOULD BE THE STANDARD OF REFERENCE, THE METER OR THE QUANTITY FOUND IN THE TANK?

Theoretically, there is hardly any question but that in running a trial quantity into a gauged receptacle, the meter ought to be stopped when the amount intended to be indicated by the meter is in fact shown by the scale, or tank; but practically this is not as convenient, nor can as accurate answers be obtained, ordinarily, as when the quantity intended to be run is *indicated*, whether correctly or incorrectly, by the register of the meter. The reason for this view of the subject is that commercial water-meters, even in the smaller sizes, are not adapted to be read less than 0.10 cubic foot; whereas any degree of refinement may be obtained in the scale. Hence, in the writer's opinion, all meter tests, especially when small quantities are run, should be by the meter. The importance of this in practice may be best understood by presenting a brief illustration.

Suppose that 10 cubic feet, regarded as 625 pounds, to have been run in a tank; but that the hand of the register is "shy" of the naught-mark; the actual extent of the error can only be judged; to accurately ascertain it, the meter must be operated until the hand reaches the dial-mark, and yet, by doing this, the exact reference quantity in the tank has been increased.

From these conditions and circumstances frequent misunderstandings have arisen; thus, as to whether when a meter was reported as "under" or "over," it in fact registered less than the tank or the tank more than the meter. All such misunderstandings would be avoided by concurrence in the following procedure and interpretation: First, that the meter be run until the intended trial quantity is indicated by the register. Second, that when the quantity found in the tank is *more* than the amount indicated by the meter, it shall then be understood that the meter under-registers, or is "under." Third, that when the quantity is found in the tank is *less* than that indicated by the meter, then, the meter over-registers, or is "over."

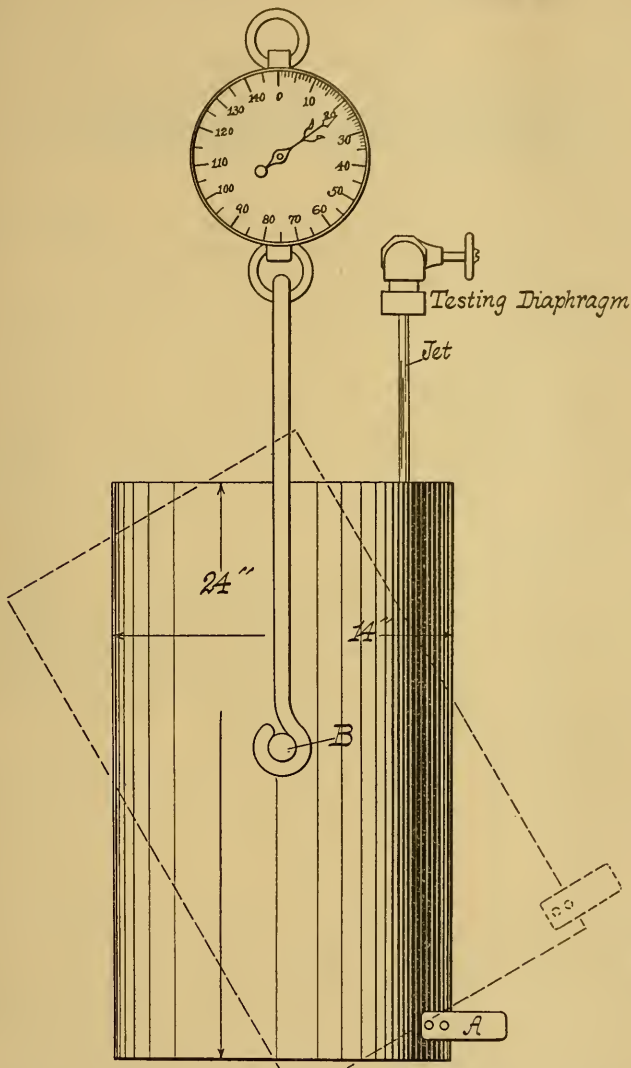
SHOULD THE ERROR OF METERS BE RECORDED IN TERMS OF POUNDS OR PERCENTAGE?

It is believed that it would be preferable if the indication of meters were uniformly denoted, on all test-cards and records, in terms of percentage of the quantity indicated. This is now done in but comparatively few cases, the usual practice being to record the error in pounds, plus or minus, or in the percentage of error, plus or minus. These three methods of recording may be quickly brought clearly to mind by assuming a meter as indicating 10 cubic feet but with 635 pounds found in the tank. This can be recorded $635-625=10$ pounds "under;" or $10\div635=1.6$ per cent minus; or $625\div635.0=98.4$ per cent., that is the exact quantity registered by the meter. To the writer at least, in a column of tests recorded in the latter way, it is more satisfying to the mind than in terms of pounds or differences.

APPARATUS FOR TESTING WATER METERS.

In testing water-meters there are two reliable systems available, namely: by weighing the trial quantity, or by the use of a calibrated tank. In European practice, graduated tanks are largely,

Plate 8.



Galvanized Iron Can Suspended on Spring Scale. Maximum Testing Capacity, 2 Cubic Feet or 15 U.S. Gallons. To Empty: swing by Handle A on Trunions B

John Thomson.

almost entirely, employed; in America, measurement by weight is most commonly in vogue. It is now believed by the writer that the graduated tank is the better system, in that there is less liability to error in observation; variations of volume due to the difference of temperature is obviated, and tests may be made in less time. There is no question, however, but that the weighing system is the cheaper to install, as with but a platform scale and an old oil barrel first rate results may be obtained.

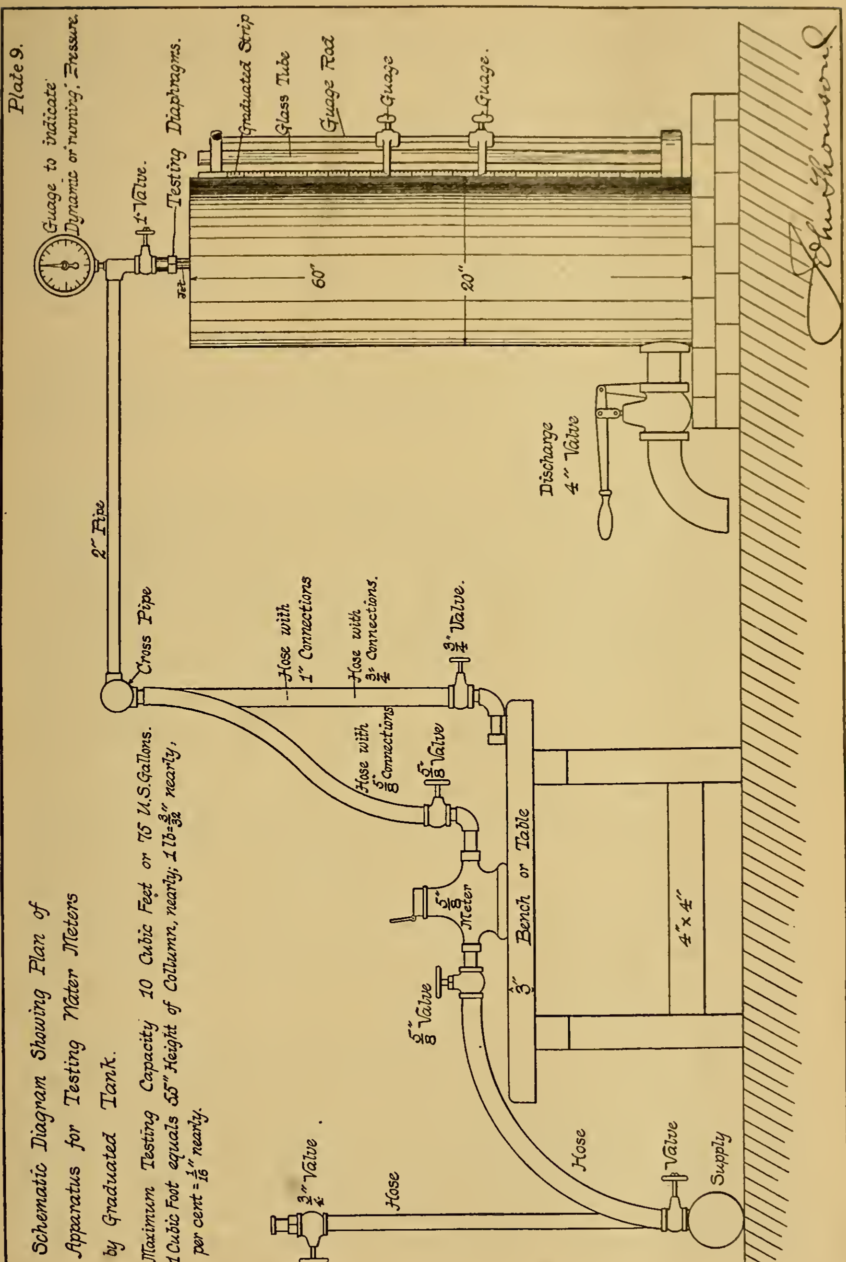
In plate 8 is shown one of the handiest, least expensive and yet accurate testing systems, known to the writer, consisting of a simple galvanized iron can, swung upon an iron axis, from which, like the handle of a pail, it is suspended from a common spring balance scale having a total indication of 150 lbs. A tank, or can, 14-inch dia. by 24 inches long will afford ample capacity for a test of 2 cubic feet. First-class results can be obtained from such an apparatus, especially where "fine-haired" testing is required. Thus within the range of the scale, 1 foot can be run at full flow; half a foot at half rate; two or three-tenths at low and as many more for the limit of sensibility.

In plate 9 is indicated a testing-plant, in schematic detail, which may be of service as a starting thought to those who may regard the installation of a reliable, convenient and durable system as worth the while. Such an apparatus, adapted to the conditions of the place, would be comparatively inexpensive and would be conducive to uniformly accurate results.

In the calibration of such a tank as is indicated in the plate, probably the most convenient and reliable method, is by carefully weighing the water and graduating the scale from the water in the tube.

In the writer's practice a number of meters are tested in series; this being done to make the time and save water. But, ordinarily, this would hardly be worth the extra cost of special fixtures. Moreover, this method involves special care and aptitude on the part of the operator to insure the ejection of air from the meters and an accurate comparison of the several indices of the registers.

While much more might be said and many details be here added, it is believed that that which might come from the practice and experience of others would be of much greater value; hence, the subject is now in your hands with this final observation: Your successful



Schematic Diagram Showing Plan of Apparatus for Testing Water Meters by Graduated Tank.

Maximum Testing Capacity 10 Cubic Feet or 75 U.S. Gallons.
1 Cubic Foot equals 55" Height of Collumn, nearly; 1 lb = 3/32" nearly,
1 per cent = 1/16" nearly.

meter-tester must be a man of parts; he should have many of the attributes of the successful fisherman, as skill, judgment and patience; and when to these are added plenty of bait and good tackle so much the more certain will be the results. And so it is in the bench-testing of water-meters.

DISCUSSION.

THE PRESIDENT. Gentlemen, you have heard this very interesting paper on this exceedingly interesting subject, and it should have considerable discussion.

MR. HASKELL. I did not hear Mr. Thomson state the degree of accuracy that we should secure, if we should adopt some uniform method of testing, that is, whether the meter should register within half of 1 per cent., or a quarter of 1 per cent, or what errors would be allowable.

MR. THOMSON. I think I did mention with reference to the sensibility test, that taking the minimum rate of one cubic foot an hour, in my judgment it is well within the power of manufacturers to turn out meters regularly that will indicate within 3 per cent. of accuracy at that rate. At the higher rates of flow, in my opinion, it is well within the power of manufacturers to produce meters that will indicate within 1 per cent. of accuracy, plus or minus. I am referring, of course to the domestic sizes, that is the smaller sizes of meters.

MR. RICHARDS. I think in this connection it might be well to consider how often in actual use a meter is required to register these extremely small streams. When a meter supplies a tank through a ball cock, it might have to supply a very small stream quite often; but that is about the only case that occurs to me, where these exceedingly small streams will be drawn, unless they are drawn purposely. So I believe with Mr. Thomson, that a meter should be purchased to fit the place in which it is to be used.

MR. MCNALLY. I think that these small streams are just the ones that we ought to try to measure if it is possible. We meet so many cranks, especially those of us who are connected with the registrar's department, when we try to collect our money, that we have a great deal to contend with, and I believe that those are just the streams that we need to look after; and if we can get a meter that is accurate, and we certainly can for we do get them right along,

that is the kind of a meter we want. Of course it is well known that water works at the present time are accepting meters that are within 2 per cent., either minus or plus; but it has been the aim of our superintendent and of myself to get meters that are either absolutely correct, or that favor the consumer if they are in error at all. We want to know for a certainty that we can show that that meter is either correct or that it is favoring the kicker. It is this consideration that has led us to say to the manufacturer: "We will not accept your meter unless it it is absolutely correct, or within 2 per cent. favoring the consumer," and we send them back unless they test that way.

I believe, as Mr. Thomson has said, that there should be some uniform method for meter testing, and that great care should be exercised in using it. We are now using discs which I think are not reamed out at all. Of course if he was testing a meter with the sharp edge reamed off as suggested in his paper, there would be quite a difference between his test and ours. I think there should be uniformity in testing, and when this is brought about there will be a better feeling between manufacturers and the water departments. It is a matter which will require considerable study, and it will benefit all concerned.

Mr. Holden. I would like to ask Mr. Thomson if, in his experience, there is any way in which a meter after it has once been adjusted can over-register? There are frequent complaints that meters are over-registering, but I never have been able to find one that did, and I would like to ask if a meter can get out of order in any way so it will over register?

Mr. Thomson. No, sir, I have never had that experience in my practice, and I don't understand how it could occur. I think it might be possible with some types of piston meters, but it will occur if at all very rarely and under very peculiar conditions, such as are not likely to arise in regular practice. I have heard that some waters deposit a sort of fungus growth upon hard rubber pistons and with them such a result has been observed, but it never has come directly to my knowledge. I think it is almost invariably the case that the meter, especially if it is run severely in practice, is liable to loose in sensibility, and therefore be in favor of the consumer.

I might say that there is one case of over-registration, which I may properly refer to here, that of the current or type of inferential meters which are quite largely used in Europe. Over-registration may be produced in such meters as the result of water ram and especially if there happens to be an air cushion in the meter, the wings or vanes of the meter being impelled forward by water reacting from the result of compression of the air, although no water is actually passing through the meter. But that type of meter has not been used in this country to any great extent.

Mr. Haskell. I would like to ask Mr. Thomson whether in the case of a piston meter operated under a high pressure, with a good deal of grit in the water, the piston might not wear sufficiently to produce over-registration.

Mr. Thomson. I really do not understand, sir, how that result could occur. It would reduce the displacing capacity of the piston.

Mr. Haskell. Suppose the piston is taken from a meter and filed down, then at each stroke of the meter the amount of water displaced would not equal that shown on the dial.

Mr. Thomson. The water would then slip by the piston and would not be shown on the indicator at all.

Mr. Williams. Is the difficulty most likely to be in the slip past the piston or disc of the meter, or in the recording apparatus?

Mr. Thomson. It is very largely, if not entirely, in the displacing member of the mechanism, the piston on the disc or wheel, whatever it may be. Any change in the recording apparatus of the meter usually is in the line of increased friction, and therefore it slowly decreases the sensibility of the meter in a long period of time. That, however, affects it only at the lower rates of flow. The actual change, in the quantity of water displaced, comes from wear of the parts; and that is one reason, as I suggested in my paper, that meters should be in almost every instance somewhat adapted for the character of their service. In my judgment it is not good engineering to fit the meter to the very finest work in sensibility, and then expect that meter to stand up under the very highest rates of delivery. Take, for instance, a $\frac{5}{8}$ meter, which may be called on to deliver, say, 3 cubic feet a minute for one minute, and the next minute you expect it to indicate at the rate of a cubic foot an hour. Under such conditions the sensibility of the meter will almost invariably be lost, especially if there is grit in the water. Whereas if the

meter is free, and there is grit in the water, the meter will last longer, and be uniformly more accurate in its registration at the higher rates of flow.

Mr. Holden. Is it advisable for the meter manufacturer to make or for the meter user to use meters adapted for extreme accuracy? Isn't it much better to look for durability rather than for absolute accuracy? There are few places in the country where the rates for water are so high as to make extreme accuracy in measurement necessary. Our charge is about 50 gallons for a cent, 20 cents a thousand gallons; and isn't it better to give the consumer a few gallons and have a durable meter, rather than to have one which is extremely accurate, which will register down to a few drops, and which will last but a short time?

The President. Gentlemen, this is a subject in which I have a deep personal interest, for I have come near getting scalped a number of times by people who, of course, didn't use any water and yet claimed that "The darned thing keeps running night and day." (Laughter.) If you will allow me just a word I will say that I have come to the conclusion that water is not so valuable a commodity but what we can afford for our own peace of mind to be sure that we are giving the consumer all we agree to give him for his money. When a kicker comes to us and we can show him that we are simply throwing water at him, that he is getting about 20 per cent. more for his money than he thought he was, then he will be satisfied, and he will tell his neighbor about it, and we will have a chance to put in two or three more meters. There are lots of consumers who think it is possible for a meter which has run accurately for six months to jump right ahead with an error of 50 per cent. against them. When you can put the meter on a bench and show him squarely and fairly that he is getting more than he is paying for, he goes away happy and settles up his bill and keeps the old thing churning, and everything is all right. But if he finds you a fraction of one per cent. in error on the wrong side, that is, against him, he will make you take the meter out and sharpen your pencil pretty fine in order to make the reduction on his bill. So for my part if I can get a meter that will run within 5 or 8 per cent. of accuracy, and have it run in favor of the consumer all the time, and have it durable, so that it is not necessary to strip it and clean it out to get it to run, and so that it will not break down but will keep going, and I can

be sure that I am not losing over 8 per cent. and with the price we are getting for our water, I don't believe but what the city is making money then, and it certainly saves lots of trouble for the man who is running the works.

Mr. Gilbert. After having had 10 or 12 years' experience with meters, I agree perfectly with what the President has just said. I don't care to spend my time, and the money which we get for water, in trying to test these meters down so very fine, while we allow those consumers whose water is not metered to waste as much as they please. Give me a meter that will register nearly all of the water, that is within from 3 to 8 per cent. as the President has said, and I can make it pay and make the consumers happy. It has been my experience that when you get a meter that registers down within 1 per cent. you have a meter which is liable to stop, and I don't want to accept such meters. I don't think the small amount of water we should lose would amount to anything, in fact, I don't believe it would amount to half as much as we should spend in testing the meters.

Mr. Williams. The point of greatest interest to me in this connection is not so much to know what we ought to expect from a meter as to know what we really do get in practice. There are some water works systems in New England, I believe, in which all the services are metered, and I think the general experience is that their pump records show about twice as much water as the meters account for, and I would like to discover the cause of the discrepancy. When we think that the average consumption in our ordinary towns for domestic supply is less than 3 cubic feet per day per person, and the average family is about five persons, it does not give an average of one cubic foot an hour, which is the rate according to Mr. Thomson, on which there may be three per cent. variation. And as the error appears to be in the displacing mechanism, corresponding to a slip in the pump plunger or through the valves, it must be possible for leakage to continue for the whole 24 hours at very nearly the same rate it would leak when the meter was moving at a slow rate, without its being recorded. So it seems to me that in those cases where the consumption is well down towards the minimum, that is where it is brought down to about 6 or 7 gallons per person, as it is in a good many places, the error in the meter must be very nearly 100 per cent. If that is so, it will account

for a good deal of the difference that we find between the records of the water meters and the pumps.

MR. HASKELL. It might be possible in a great many places to get even a greater discrepancy than that, as for instance, in the stock yards in Chicago, where it is stated that they had a meter there which was measuring one million gallons of water, and there was another pipe which was delivering forty-eight millions unmetered at the same time. Where they operate water works in that way, it would be hardly a fair thing to put on meters with a slight discrepancy. Now Mr. Thomson has stated to us that he is prepared to furnish us meters that on any stream a taker is liable to use, will measure the water within one per cent. I don't think he can quite call it one per cent., because, as I understand him, he means one per cent. under or one per cent. over, so it is really two per cent., and the other figure I understood him to give was was three under and three over, which means six per cent. variation, But there wouldn't be much of any water lost anyway when a meter is delivering these small streams. Now I don't believe there is any meter man in this room but will agree to do this with his meter. I know I have no difficulty in getting meters which will test within one per cent. If you are a little bit particular about your meters, and they know you want them accurate, and you tell them the streams on which you want to put them, they will furnish you the goods. There is no trouble about getting what you want if you insist upon it. There can be no excuse for putting a meter on which is going to register against the consumer. It puts you in a very bad position, when a consumer comes to you with his complaint, if you have to admit that you knowingly put on a meter that was going to oblige him to pay more money than he ought to pay, and we make it a point in our city never to put on meters that over-register. We mean to get as near to one per cent. as possible, and though we don't always get it, we do come pretty near it. I don't believe that there is the least difficulty in getting meters that will register within two per cent., and from that under, from almost any of the meter men who are here. This meter business has been growing very rapidly within the past few years, and the manufacturers are giving us good goods, and in my opinion we ought not to let up at any three or eight per cent.

MR. WINTHOP. In our system we pump directly into the circu

lation, the surplus going to a tank. We have a long line of 8-inch pipe nearly on a line between the pump and the tank, but going to a dead end beyond. A half-inch connection was made with this main near the end, some four or five years ago, and that was metered. The bills used to be very high, from $6 to $8 a month. The consumer complained of white water and lots of air. We took the meter off and tested it a number of times and found the meter correct, or very nearly correct, a little in favor of the consumer. He wanted it tested in its usual position, and I concluded to do so, and found that he was paying for air, and that the meter was registering about double the amount of water that came through it.

MR. CHASE. The function of a water meter is two-fold. First, it acts as a machine to aid in proportioning the cost of water among the consumers in proportion to the amount of water they use; and secondly, it acts as a sort of police in preventing waste. By keeping people from permitting the water to run to waste through leaky fixtures or otherwise, the consumer is afraid of the bill which the meter will run up by excessive use of water, and the mere fact of a meter being on will lead the consumer to look after the fixtures and not allow leaks to remain unattended to. Now it is all very well to talk about allowing 2, 3, 4 or 5 per cent. loss of registration, but if a meter allows 1 or 2 per cent. to pass without registration, the small leaks will grow in frequency when the consumer finds out the meter does not detect them. I think those of you who have such meters will soon find out you are furnishing a great deal more water than you are getting paid for. It is a pretty good meter, I think, that under ordinary conditions, after a little wear, will register accurately a cubic foot of water an hour. That in the course of a day amounts to 180 gallons. If that is running continuously, at an average price, we will say, of 20 cents per thousand gallons, that amounts to over $13 worth of water per year, and is just about the amount of water that a person would be entitled to who pays the minimum water rate. Now, if a consumer finds out that his meter does not register small leaks, he will take very little cognizance of them, especially those in the average water closet. For that reason I think it is not advisable to put on meters which will not register within 1 per cent. to start with, and they ought to be looked after pretty sharply to see that they do not get more than 3 or 4 per cent. away from accuracy.

Mr. Lockwood. I don't believe in encouraging meter manufacturers to make poor meters. They are now making meters that are quite accurate, and I think we ought to hold them there. We all know that after a meter has been in use a little while it naturally wears and will pass water without registering. Now if you start with 6 per cent. loss you are soon going to get up to 8 or 10 per cent. loss. We endeavor to keep our meters within 2 or 3 per cent. and I certainly should not recommend a meter that did not come nearer than 8 per cent.

The President. I would say in connection with figuring on 8 per cent. that that was the loss on a small stream; if the stream is very small the meter does not register. If you are drawing only a cubic foot an hour, and your per cent. of loss is the same as at higher rates, the loss isn't very heavy in any case. I think we all want a meter which will register whenever there is any appreciable amount of water drawn through it.

Mr. Noyes. In other words, Mr. President, I understand that your idea is that on very small streams, as when a faucet is leaking drop by drop, you consider there should not be more than 8 per cent. error, and that this per cent. should not apply on the ordinary working of the meter.

The President. That is the idea.

Mr. Noyes. I think that Mr. Williams of Detroit has hit the matter about right. The great value of the meter, as I understand it, is to prevent the little wastes, the leakages from the faucets and water closets when the water is not being drawn. I know in my own house, that by being careless in not having the faucets fixed, I have had to pay quite a sum of money, an amount far in excess of what it would have cost to have had the fixtures repaired. There is one interesting point that Mr. Williams made, in regard to the very large amount of water that cannot be accounted for by meter registration. I have in mind an instance which we found during the investigation which has been recently made in connection with the proposed new water supply for the Metropolitan District of Boston in one town where the water was purchased entirely from a water company, and every fixture in the town was metered, and they could account, under the very best conditions, for only from 50 to 60 per cent. of the water. And I think that in other towns where the water is metered,

about the same ratio of water could be accounted for. In the case of Newton, where, a very large percentage of the fixtures are metered, and by assuming for the remainder, the rate of consumption per person, as determined by Mr. Whitney in his series of observations made at Newton a few years ago, (the results of which were published in the**Journal* of the Association), the actual consumption is much greater than the amount of water which can be accounted for by the amounts measured.

Mr. Gilbert. Perhaps I ought to explain my position a little more in regard to this matter. I don't want any of you gentlemen to think that I believe in poor meters. We have had considerable trouble with meters regulated so closely that they would gradually record less and less and finally stop. I think the loss would be less by having a meter which was not so closely adjusted that it would gradually stop. I think if you get a meter which will run regularly and will not stop, even if there is a small loss, it is better in the end.

Mr. McNally. I think the conditions of the work should govern the selection of meters. If the works have water with but little grit in it, it is certainly possible to use a meter that is built a little closer, and in which there is not such chance for slip as there must be in a meter passing a mixture of sand and water. Of course we don't want a meter to measure drops, but the manufacturers can make meters that are strong enough to wear ten years. We have taken them off and tested meters that had been on services for ten years and we have found that they had stood the wear in good shape and tested all right.

In regard to accounting for the water, it would seem to me that if the taps are all metered, and the meters are not indicating all the water pumped, other parts of the system should be examined for leaks. Joints, for instance, may need attention. It is certainly unfair to blame the meters for not showing the amount of water, instead of looking in the ground, or in the culverts, and elsewhere to find where the water is escaping, perhaps through the fault of some contractor who made the joints out of oakum and used very little lead. I think that will account for a good deal of lost water.

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*Vol. VI. p. 39.

A MEMBER. I think if our meter manufacturers can give us a meter which will register within 5 per cent. of the amount of water passed, and which will give us no trouble in repairing, cleaning, etc., we ought to be satisfied. When a man knows that a meter has been put on his service, that knowledge is enough to prevent him from wasting water, and he is going to use just as little water as he can. As far as detecting leaks is concerned, we look to our inspector for that, and what few leaks do not come under the observation of the inspector would not amount to a great deal.

MR. THOMSON. May I say just a few words more. If the President had stood by his first proposition, I think we could make his meters in a brass foundry. In reference to the moral effect of a meter, I have a friend who believes that a meter casing without any interior is amply sufficient to do the business. (Laughter.) I believe Mr. Williams, of Detroit, made a point, if I understood him correctly, which I did not intend to convey in the paper, namely, referring to an error, we will say of 5 per cent., if you like, in the meter at a low rate of flow, and by that I mean in a domestic size indicating down to 1 cubic foot an hour. Now that error need not continue at the higher rates of delivery, except possibly when the meter is driven at a very high rate of flow. If it is driven at a very high rate then it may under-register, because the water will be driven by it. But any of the rotary meters on the market today, can be made to indicate within 3 to 4 or 5 per cent. of accuracy on a rate of 1 cubic foot an hour, and that error will not be shown in the registration at the higher rates of flow. When you get a rate of flow of say 1½ or 2 cubic feet an hour, and from that up to the proper capacity of the meter, the registration of the meter should be, and almost invariably will be, accurate; and the original slip or error at the very low rate need not show at higher rates. And the same with regard to the point made by the President. The error at the minimum rate may be 8 or 10 per cent., and yet not be shown in the registration of the meter at the high rates of flow.

There was a point made by Mr. Noyes that I think has been very fully brought out in a paper recently presented to the American Society of Civil Engineers by Mr. Dexter Brackett, and which I believe will be published in probably the next number of its trans-

actions.* I think the data that Mr. Brackett has collected in regard to the subject are of the very greatest value. As I recollect he referred to Yonkers, to Worcester, to Fall River, and I know to Woonsocket, and I must say I was greatly surprised to find so great a discrepancy possible. I was surprised to find, as is set forth in my discussion of Mr. Brackett's paper, that the difference in the amount indicated by the meters and the amount which they believed they pumped, could be accounted for in almost all of those instances by a rate of flow of a cubic foot an hour on each of the services of the several cities and towns. It amounted to a great deal more than I thought was possible.

Mr. Haskell. We have heard a good deal about the loss of water, and all of us ought to know something about where there is a loss of water in our water supply systems. If a person will think for one moment of the amount of water that can escape in 24 hours through a $\frac{3}{4}$-inch pipe or a $\frac{5}{8}$-inch pipe, and then look at some of the water-closets and at the streams of water that run into them,—and if he wants to get instances of that he can send an Inspector around in any town or city and he will find a half dozen water-closets tied down and running full streams,—he will know where a great amount of water is wasting. I don't believe there is one of us but what can find such cases. I know my men are finding them almost every day, and it doesn't take many of them to account for a good deal of discrepancy between the amount of water pumped and the amount metered.

Mr. Williams. Mr. President, I think from the reply which was made to my former remarks, that they must have been somewhat misconstrued. Let us assume that an average person requires 3 cubic feet of water per day, and that the average family consists of five persons, that calls for 15 cubic feet of water to be delivered through the ordinary domestic meter in 24 hours. Now your error of 3 per cent. at the rate of one cubic foot per hour will account for about $\frac{5}{8}$ of a cubic foot of water, which is lost. The 3 per cent. at that rate is going on for the whole 24 hours, whether the meter is moving or not, if there is a leak and with a flow of that sort, it may come up to very nearly a cubic foot in a day. Now take a case where the consumption is down so that instead of its

*Trans. Am. Soc. C. E. 758, Vol. XXXIV., Sept. 1895.

being 3 cubic feet per person per day, it is, say, but ½ of a cubic foot per person, as it is in some cases, and you will see that that same loss may occur and be going on continuously. So that where a family is actually using, or is assumed to use 2½ cubic feet of water per day, and the meter registers that, the actual consumption is 3½ cubic feet, or it might be even more than that. That is what I mean by saying that the percentage of loss would increase very greatly on smaller services. Now, as a matter of fact, in the city of Detroit about 20 per cent. of our services are such as we would expect to consume under 8 gallons per person per day, and 80 per cent. of them consume less than 20 gallons per person per day. So it is apparent that the chances are that errors will result vastly greater than 3 per cent.

A MEMBER. Where meters are applied on Chinese laundries, John quickly finds out the maximum rate of flow, which his meter will not indicate, and then he collects the water in his pans and tubs at that rate of flow. (Laughter.) In that case it is necessary to have a meter which will be of the very highest sensibility, and sometimes meters have been put in which would over-register a little bit at the higher rates of flow, and in that way the accounts have been balanced.

MR. COGGESHALL. We have a Chinaman in our town who can give that one points, for he takes the water out of the public drinking fountain. (Laughter.)

MR. BOOKE. I would like to ask the gentleman from Detroit if he has considered whether his pumping machinery is delivering water at every revolution as he expects it to? It strikes me that there may be loss there. I know we found it so in Princeton. Nine years ago it was a problem with us how we were to continue to supply water from the source we then had with the demand which was being made upon it. The meter companies came to our relief. We put meters upon every tap upon our mains, except the hydrants, and today we are not supplying a drop of water to any one except through meters. We immediately increased our revenue 100 per cent., and we have increased the number of consumers 100 per cent., and we are doing this with the same amount of water we were pumping nine years ago. And so I favor the meter manufacturers, and I think we ought to encourage them all we can.

The President. We have discussed this question pretty thoroughly, and I think we have obtained much information, and some of us, perhaps, have said some things which we did not exactly believe ourselves. (Laughter.) Five to eight per cent. of error seemed to scare some of you when I mentioned it, but when a metre man said he would give you a meter which would register within three per cent. over or under, and that is six, that did't seem to frighten you at all. Now I think perhaps we have been here long enough, you have given very close attention, and as it is now after 5 o'clock we will adjourn untill evening.

TESTS OF ARTICLES OF COMMERCE, TO BE CONDUCTED BY THE ASSOCIATION.

BY

Clemens Herschel, Supt. East Jersey Water Co., New York.

[Read September 12, 1895.]

It may be known to many of our members that the Pennsylvania railroad has a testing laboratory at Altoona, Penn.; an establishment employing from twenty to forty skilled men, among whom are several prominent civil and mechanical engineers, chemists, asssistants and mechanics. It is their duty to advise the company in the purchase of materials of every sort, whether a manufactured article, such as car-springs, boiler-tubes, and the thousand other things purchased on a railroad like the Pennsylvania; or substances that may more properly be called raw materials, such as oils, paint, iron, steel, etc.

To do this intelligently, the laboratory is constantly engaged in tests of articles of commerce, as supplied by different makers and dealers. That it pays to conduct such a laboratory, its existence and appreciation on a railroad like the Pennsylvania, for the past twenty years, should be sufficient proof.

Similar work to that done by the Altoona testing laboratory has also been done by the American Association of Railroad Master Mechanics. Quite recently a committee of the association has reported the results of tests of some twenty odd makes of brake-shoes, now on the market.

The Manufacturers Mutual Fire Insurance Company of Boston, does similar work in behalf of its members, and reports the results by circular.

Wherever a body of men are interested in having such work done, it is evidently economy to have it done and the results reported at the common cost, rather than to leave each one to shift for himself.

It is therefore proposed that the association shall, from time to time, cause sets of tests of the sort described made at the expense of the association, by committee or otherwise, and that the results be reported by circular or in the Journal.

As a beginning in this direction, I suggest a test of all the ordinary house water meters, now on the market. A test of this

sort, it will be remembered, was made by the city of Boston in 1888. But such has been the rapid advance of meter manufacture since then, that the results of 1888 are of no use in 1895. Few of the meters then tested, are yet manufactured, and many new ones have since then been put upon the market. And it may well be, that, tests now made, would have to be repeated once or twice, at intervals of seven years, in order that false principles and methods of construction may get definitely culled out, and the manufacture of water meters be put upon a satisfactory basis.

The reason I have suggested the test of water meters as a beginning, is because I have had a little experience in this direction during the past winter, which I will describe for the benefit of the association; and from which the association may judge for itself whether tests such as are here recommended are instructive or not.

I bought in December, 1894, one each of seven different makes of $\frac{5}{8}''$ water meters, which, for the present, I will call 1, 2, 3, 4, 5, 6, 7.

They were tested for accuracy, and for loss of head caused by the meter, at various rates of discharge. Then about 100,000 cubic feet were allowed to pass each meter, and the first set of tests were repeated. Then some 150,000 cubic feet additional were allowed to pass each meter and the first named tests were again repeated. The quantity passed was equivalent to some ten years of ordinary use.

Incidentally, therefore, these tests comprised a test for durability. Tests were also made for sensitiveness; and a test for remaining unaffected by long continued disuse, is still under way.

The results were somewhat remarkable. They are given in the following table:

	First Test.							Second Test.							Third Test.						
	Rank.							Rank.							Rank.						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Accuracy....	2.	1.	6.	7.	5.	3.	4.	1.	2.	3.	4.	5.	6.		1.	2.	3.	4.	5.	6.	
Sensitiveness	1.	5.	2.	3.	4.	7.	6.	1.	5.	2.	3.	4.	6.		s 1.	a 2.	m 5.	e 3.	6.	4.	
Permanency.								4.	1.	2	3.	5.	6.		1.	2.	4.	3.	5.	6.	
Loss of Head	4.	1.	7.	3.	2.	6.	5.	4.	1.	3.	2.	6.	5.		4.	1	3.	2.	6.	5.	
Price........	1.	sa 3.	me 2.	6.	7.	4.	5.														

I will call attention to only one point: the three cheapest meters have been shown to be the three best ones; and I will leave it to the business sense of the members of this association whether a result of that kind is not worth discovering.

It would not be assumed, to begin with; and would hardly be matched were the tests to be made of watches, clocks, shot-guns or bicycles. It has often been claimed that "the cheapest is the best," but here is a case where the best is the cheapest.

It may be that a test of all the meters now on the market, would modify the conclusions reached from this reported test of only seven of these meters, but the point sought to be presented to the association is, that it pays to test articles of commerce, and that such work, to be undertaken for the benefit and instruction of its members, is a proper thing for this association to undertake and pay for.

To do so would be entirely in line of furnishing instruction to its members that cannot otherwise be obtained, which has so prominently obtained as one of the duties of the association hitherto.

DISCUSSION.

The President. As I understand it, Mr. Herschel suggests that the association should take up the matter of testing different meters and stamping them with its approval or disapproval, or with the results of the tests, and that the tests should be made at the expense of the association, for the benefit of us all. The subject is now open for discussion. Have the meter men all gone home? (Laughter.) If they have, the meter users have not. We would like to hear from Mr. Cook of Woonsocket. I think he has some ideas on this subject.

Mr. Cook. There are various kinds of meters in the market that are doing good work, and I was very sorry yesterday to hear some member say that within four or five per cent. of accuracy was good enough for a meter. I don't want the meter manufacturers to get the idea that we are going to be satisfied with that kind of a meter. I know that it is impossible to get a meter that will register accurately in all cases, with low flows and also with high flows, but the meter which is demanded in houses with modern plumbing is a meter which will detect a small leak, but which will also allow a man to use his lawn sprinkler, and will measure both accurately.

Mr. Noyes. The idea advanced by the writer is certainly a novel one, and since I have heard the paper read I have been turning over in my mind the practicability of having such tests as Mr. Herschel suggests made by the association. It seems to me that while the idea has some things in its favor, it would be very difficult to carry it into execution. Mr. Herschel himself has apparently found that in speaking of the tests he has made, it is not prudent or proper to speak of the various makes of meters, but he has designated them only by numbers. Now, the test which he refers to as having been made by the city of Boston in 1888, was conducted by honorable men, who were above reproach, and yet that test was severely criticized by men who were interested in the various meters.

It has seemed to me further that the conditions under which meters have to work are so different in different places that any test which might be made under the auspices of the association, might not be satisfactory for all the conditions encountered in various works. I think it is perhaps within the scope of this association to formulate methods of testing which might be more satisfactory than those now in use, but it does seem to me that the testing itself must be done, and the decisions reached by the individual departments, and that the officials in each place must determine what meter is best for their particular use.

The Secretary. In reference to the Boston tests, it might be well to say that as a result of those tests, which cost, I think, some ten or twelve thousand dollars, the meter which was considered the best by that commission has never been known commercially, and the meter which was considered the second best has had only a very limited sale.

Mr. Noyes. That is, in practice, the meter which had given the best test proved to be a practical failure.

The Secretary. It was a failure commercially.

Mr. Thomas. A few years ago an attempt was made to get the Massachusetts legislature to provide for the appointment of a special commission to test meters and approve them, and the members of this association were practically unanimous in their opposition to it, quite a number of them presenting themselves at the meeting of the legislative committee on water and opposing it. And I think that if a committee of this association were to test the various meters now on the market, the result would be that it would approve of every

one of them. I think that if the plan proposed by Mr. Herschel should be put into practice by this association it would be a complete failure.

Mr. Noyes. My attention has been called to one difference between the test proposed and those which are spoken of in the paper as having been conducted by the master mechanics of various railroads. The great benefit derived there is the securing of uniformity, which is necessary on account of the interchange of cars between the railroads, and the consequent necessity of having uniform appliances.

Mr. Haskell. Mr. Herschel's paper presents in a general way some reasons why this association should go into the meter business. The time has not yet arrived, I think, when we ought to do that. Then, again, any water department that hasn't ability enough among its own members to test meters properly, could not, I think, be assisted by outside help so that it could run its business any better. (Laughter.)

Mr. Smith. It seems to me that it is eminently the duty of this association to adopt, as other societies have done, a comprehensive and uniform system of testing water meters, so that we may have the benefit of comparisons of tests made upon a common basis. I think that was recommended very strongly yesterday by Mr. Thomson, and I believe that such action by the society would be a great benefit to all of us, both the users and the manufacturers of meters.

Prof. Swain. Mr. President and fellow members: I agree thoroughly with what Mr. Noyes and Mr. Smith have said in regard to this subject. It seems to me that any association of this kind, any scientific or technical society, should avoid the thing that Mr. Herschel suggests, that is, going into the testing of commercial appliances and reporting the results. I think the proper function of such a society, when it is asked to do anything in that line, is simply to lay down standards for tests. I have been trying to recall any case where a society of this kind has gone into the work of commercial testing, but I have not been able to think of one. Societies have adopted standards for testing materials, boilers, etc., but I do not think of any that has ever gone into commercial testing and reporting of the results. A good many of our members, both active and associate, are interested in meters, but it does not strike

me as quite the proper thing for this society to go into the business proposed. I should think that the work of testing should be left to the companies, individuals or communities using the meters, just as the testing of materials used by railroads is done by the several railroad companies, and not by any railroad association.

Mr. Richards. I do not see why we should do anything more as an association than to indicate the methods by which tests should be made. When it comes to making the tests and telling which meter is the best one in our opinion, it is very possible that we might differ among ourselves; and I see no reason why we should do so any more than we should test cast-iron pipe and tell which manufacturer in our opinion, makes the best iron pipe or who makes the best hydrants or gates. We might indicate the proper tests for all these things, but I see no reason why this association should make the tests. That would be an interference with commerce.

Mr. Herschel. In closing the discussion by letter several months after the event, what evidently demands the most attention, are misconceptions, to be set right.

The President starts the discussion by saying, that, as he understands it, meters are to be stamped with the approval, or the disapproval of the association. But no such suggestion is made in the paper. It is one thing to give an opinion; it is quite another thing to report facts, and let the reader form his own opinion. In the paper, I suggest the determination and the reporting of facts, being the results of tests; and whatever opinion any member chooses to draw from determined and reported facts, he should be welcome to. If certain meters cannot bear the statement of the facts appurtenant to them, it is no duty of any member of the association to aid in the preservation of ignorance concerning these and other facts.

Mr. Noyes infers that I did not think it prudent, or proper, to mention the names of the meters tested. I did not do so, because I wanted the association to have the honor of a first publication for itself, and because a publication of meter tests should be made following an exhaustive test of all the makes of meters on the market; whereas, I had tested only seven. The conditions referred to by Mr. Noyes, under which meters work in practice, could, and should, all be reproduced in a series of tests. The same tests could also be made with different waters, as found at different places. I see no difficulty on that score.

Mr. Noyes' later remark, that the work of the Railroad Master Mechanics' Association was in line of striving for the uniformity that is requisite in the interchange of cars, is singularly inappropriate for the case cited, of tests of brake-shoes; in which the only thing sought for, is the greatest amount of wear of brake-shoe, for a dollar's worth of shoe.

The Secretary says, the meter considered best by the 1888 Boston commission, "has never been known commercially." This and two succeeding references to the underlying fact, are all expressions of many possible meanings. As I understand history, the meter referred to has never been placed on the market; and as not being on the market at the time, ought, perhaps, never to have been tested. It would certainly be a good rule to test only meters that have had a certain prescribed extent of sale with the public. Otherwise, models could be sent for test, and excellent results could be achieved by meters that cost impracticable sums of money to manufacture.

Mr. Thomas is under the impression, being perhaps misled by the President's introduction, that the association is to approve, or disapprove of meters, and that to attempt this would be "a complete failure;" and I think it would be, to attempt this thing. But that does not militate against a plan to have the association determine facts for the benefit of its members, and to give the members the benefit of facts procured by joint labors and at the joint expense.

I suggest to Mr. Haskell, that the association could make a series of tests of meters which, in completeness of results gathered, would be beyond the ability, pecuniary and otherwise, of many members of the association.

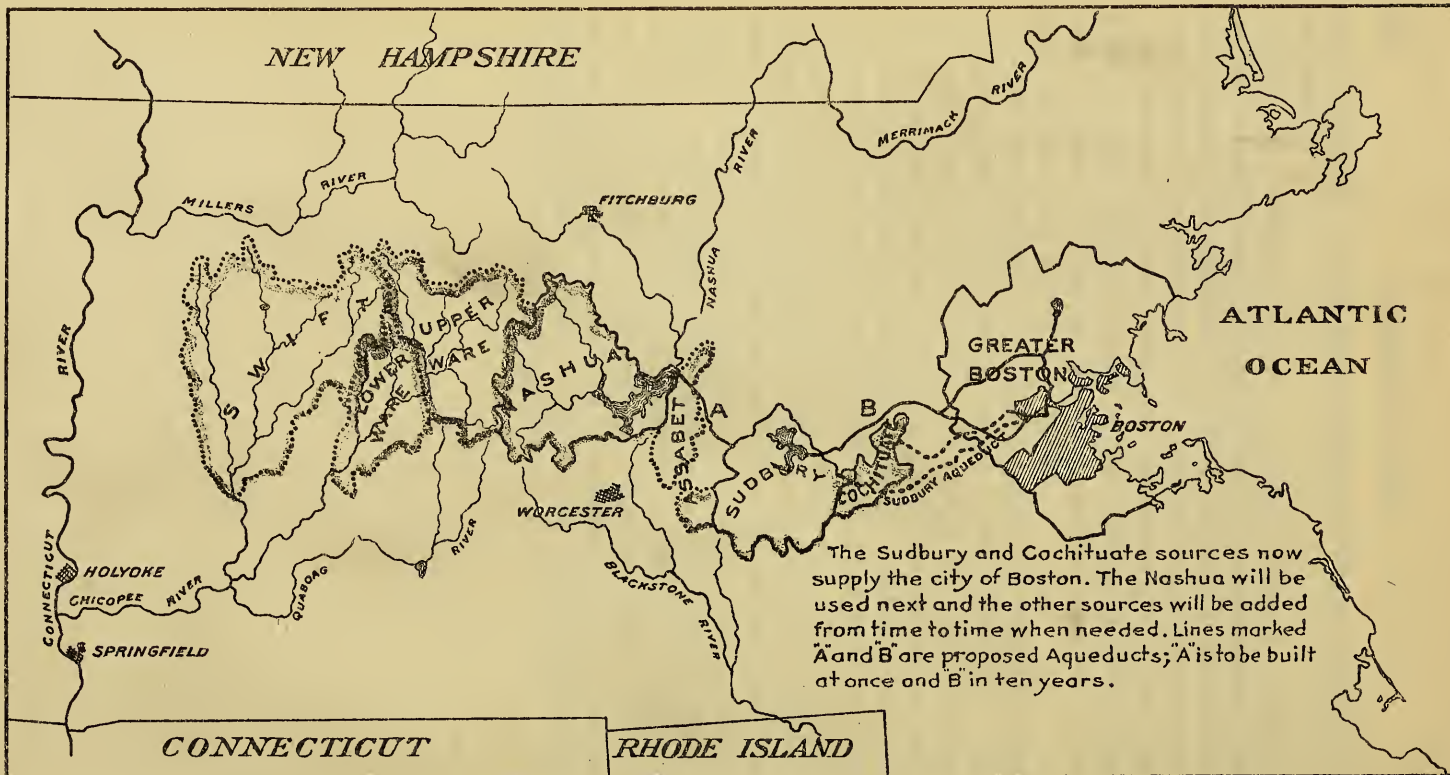
Prof. Swain cannot "recall any case where a society of this kind has gone into the work of commercial testing." I mentioned the Railroad Master Mechanics' Association, a very parallel case to our own association, and I could undoubtedly find others, here and abroad. The reference made by Prof. Swain to no tests being made by any railroad association, is again unfortunate, for he surely must know of the railroad associations that test patents, and report the results to the members of the association. Prof. Swain himself has tested trolley-car fenders, and other railroad and railway appliances, and reported the results for the benefit of trolley railways, and of railroads, and of the traveling public. This, no doubt, was a severe ordeal for poor contrivances and inventions to pass through, but it

was a welcome one for the good contrivances to be called upon to encounter.

To me, the difference between a mutual insurance company, a railroad company operating many railroads, or an association of railroad companies, or a railroad commission paid by the railroads of a certain state; a master mechanics association, or an association composed principally of water works superintendents; in each case doing work in which all are interested, at the joint expense of all, and with the intent of letting all know the results of such work—is no such difference as is worthy to be named.

As for either the felt, or an expressed fear of interfering with commerce, that must, at the last, stand for mere cowardice. This is a world of survival of the fittest. Nobody can complain, if observed facts go to show that this, that or the other thing has become unfit.

The several public tournaments of turbine wheels that have been had in the United States, undoubtedly took a great many gimcrank turbines out of the market, some of them of an alleged one hundred and more per cent. efficiency; but they have reduced the number of makes of wheels on the market, as no other process could have done, and have been a blessing to the buyer of turbine water-wheels for all time. A little of this sort of sifting out, would further the use of meters, and would improve the make of meters on the market, in one year, as no twenty years will otherwise accomplish. And to accomplish this, I again submit to the association, is a worthy and proper thing to do by a body of water works superintendents associated, as they should be, for the common good.


NEW HAMPSHIRE
ATLANTIC OCEAN
CONNECTICUT
RHODE ISLAND
MERRIMACK RIVER
NASHUA RIVER
MILLERS RIVER
FITCHBURG
GREATER BOSTON
BOSTON
SUDBURY AQUEDUCT
A
B
SWIFT
UPPER WARE
LOWER WARE
NASHUA
ASSABET
SUDBURY
COCHITUATE
WORCESTER
BLACKSTONE RIVER
QUABOAG RIVER
HOLYOKE
CHICOPEE RIVER
SPRINGFIELD
CONNECTICUT RIVER
The Sudbury and Cochituate sources now supply the city of Boston. The Nashua will be used next and the other sources will be added from time to time when needed. Lines marked "A" and "B" are proposed Aqueducts; "A" is to be built at once and "B" in ten years.

THE METROPOLITAN WATER SUPPLY OF MASSACHUSETTS.

AN ADDRESS DELIVERED BY

ALBERT F. NOYES, C. E., BOSTON, MASS.,

September 13, 1895.

Mr. President and Members of the Association: The President has said that you are to listen to a paper on the Metropolitan Water Supply, but the hour is so late that I do not think it right to take more of your time than is necessary to give a general synopsis of the work which has been done and is to be done to obtain a supply for the metropolitan district of Boston.

This is probably an old question to many of you, for it has been thoroughly discussed by many members of the association who are officials of the water departments of the various municipalities in the vicinity of Boston, but there are undoubtedly some members of the association who will be interested in a brief account of the work at this time. It is to be regretted that Mr. Stearns, formerly chief engineer of the State Board of Health, and now chief engineer of the Metropolitan Water Board, who has had immediate charge of the investigation, and to whom is due the credit for devising and bringing forward the plan which has been adopted, is not here. He has taken personal charge of the work from the first and all questions have been carefully considered by him.

Within ten miles of the State House at Boston there are 28 municipalities, having a population at the present time of very nearly 1,000,000 people. Most of these municipalities are supplied with water from independent works, generally from sources in their immediate vicinity and of very limited capacity, in fact the capacity of all the sources has been very nearly reached at the present time. It is estimated that the present capacity of all the sources now in use, in a dry year, is 83,700,000 gallons, per day. The consump-

tion of water in 1894 in the metropolitan district was 79,043,000 gallons per day, or 21,000,000 gallons more than was required in 1890.

The only sources which furnish water of suitable quality, and which could be made to supply more than 4,000,000 gallons each per day, are the Boston and Cambridge sources. The Boston sources when more completely developed will have a capacity of 62,000,000 gallons per day, and the Cambridge sources 13,000,000 gallons per day. The Boston sources, exclusive of Mystic lake, which should be abandoned on account of the inferior quality of its water, lie from 15 to 30 miles westerly from the city. It is to be regretted that the large map which has been prepared was too large to be brought here, but a smaller map, which may be seen by some of you clearly, and which can be examined later by any who wish, shows the various watersheds that are in use at the present time for supplying the city of Boston; and it also shows the watersheds which it is proposed to bring to Boston as they are required as a source of supply for the district, and which I will describe later.* I would state that this colored area is the watershed of the Mystic supply, which was originally taken by the city of Charlestown, and which now supplies the Charlestown, Chelsea and Everett districts. The blue color represents the Cochituate watershed, which was the first water supply of the city of Boston outside of its own limits. The red color represents the watershed of the Sudbury river, which was brought into use by the city of Boston between 1875 and 1880.

The Cochituate and Sudbury supplies are connected with the Chestnut Hill reservoir, the principal distributing reservoir of the city, by aqueducts capable of carrying much more than the sources will now furnish.

All sources within 100 miles of Boston were considered, but only three were found worthy of special investigation. These three being the Merrimac river, above Lowell, Lake Winnipiseogee and the Nashua river which was adopted.

After careful and extended study it was estimated that the population of the Metropolitan district would reach 2,000,000 in 1920, and that the average consumption of water at that time would be nearly 200,000,000 gallons daily, and no source of supply was con-

*See Plate I. for general location of water sheds now in use and those to be added.

sidered unless capable of being so developed as to yield this quantity of water in connection with the existing supplies.

Among the smaller sheds which are incapable of yielding this quantity might be mentioned the Ipswich river which is north of the metropolitan district and has a drainage area of 97 square miles above Topsfield. Further up, near the insane asylum at Danvers there is a favorble point for taking a water supply from it, and there the watershed has an area of 54 square miles. It is probable that sites could be found for storage reservoirs large enough to allow supplies of 29,000,000, or 16,000,000 gallons daily to be obtained from the points mentioned respectively; but these are obviously too small quantities to be seriously considered for metropolitan water supply.

The lakes in Plymouth county, particularly the largest of them, Assawompsett pond, were considered, but the supply that could be obtained was insufficient, and it was already in use to supply water to the municipalities in the southern portion of the state, New Bedford and Taunton, and possibly will be required in the future for other municipalities, Brockton or Fall River. So it was out of the question to try to develop these sources, aside from the large cost of having to pump the water, which is avoided in the Nashua river plan adopted.

The Charles river and the Shawsheen river were also considered, but the limited area of the Shawsheen watershed and the heavy population upon that of the Charles prevented their adoption.

Lake Winnipiseogee was more seriously considered. It was found that it would be necessary to construct a conduit some 84 miles long, and that the supply that could be obtained from the lake by drawing it down five feet when necessary would be 208,000,000 gallons per day, and the estimated cost, not including the water damages, was $34,000,000. The heavy cost of construction, together with the large cost which would be involved for water damages, precluded its further consideration. Lake Sebago, near Portland, was also considered, but its great distance from the city and the great expense of obtaining the water, aside fiom the cost of pumping, did not warrant the adoption of that source of supply.

The Merrimac river, above Lowell, was also considered. Owing to the very large population of the cities upon its banks the water of

the river is entirely unfit for use in its natural state, but it could be purified by suitable sand filtration. Plans and estimates were made for such filtration, but the cost, including the capitalized cost of pumping and filtration, was $17,463,000, or nine-tenths as much as the estimated cost of the Nashua river project, and the board decided that the increased cost of the latter was more than offset by the advantages of natural purity and of a gravity supply, and so this was also thrown out of consideration.

The State Board of Health has had charge of the water supplies for several years, and this work has been under the personal supervision of Mr. Frederic P. Stearns, their chief engineer, from the time of his appointment in 1887 until his recent appointment as chief engineer of the Metropolitan Water Board. In his investigations Mr. Stearns early came to the conclusion that a Metropolitan water supply would be necessary, and his attention was called to the watershed of the south branch of the Nashua river, which is just beyond the Sudbury watershed and above the city of Clinton.

Immediately above the Lancaster Mills in Clinton there is a very favorable site for a dam. An area of 6.5 square miles, shown on Plate I., will be flooded by the construction of a dam 145 feet high and 1,250 feet long, and the reservoir thus formed will contain 63,000,000,000 gallons. The enormous storage capacity as compared with other celebrated reservoirs is well shown by Table I. From this you will see that reservoir No. 6, the recently constructed and largest of the reservoirs connected with the Boston system, holds only one-ninth as much water as the dam to be built upon the Nashua river. The new Croton dam for the supply of New York city, although considerable higher, has a capacity only one-half as great, and the world renowned dam at Vyrnwy, Wales, for the supply of Liverpool, has less than one-fourth of the capacity of the Nashua river dam.

The estimated cost of the reservoir with the land to be taken for its site is over $9,000,000. This sum includes the cost of removing from the site of the reservoir all of the surface soil and everything containing more than a very small amount of organic matter.

It is calculated that in a dry year this reservoir will yield 105,000,000 gallons of water per day, which taken in conjunction with the present Boston supplies from the Cochituate and Sudbury rivers, will make a total yield of 173,000,000 gallons per day.

TABLE I.

Comparative Table of Areas, Depths and Capacities of Storage Reservoirs, with Heights and Lengths of Dams.

Name and Location of Reservoir.	Area Square Miles.	Average Depth, Feet.	Maximum Height of Dam.		Length of Dam, Feet.	Capacity Million Gallons.
			Above Ground.	Above Rock.		
Swift River, Mass	36.96	53	144	...	2,470	406,000
Nashua River, Mass	6.56	46	129	158	1.250	63,068
Nira near Poona, India	7.25	27	100	...	3,000	41.143
Tansa, Bombay, India	5.50	33	127	131	8,770	37,500
Khadakvasla, Poona, India	5.50	32	100	107	5,080	36,737
San Mateo, Cal	.....	..	170	...	.....	32.000
New Croton, N. Y.	....	..	157	225	1,270	32,000
Elan and Claerwen, Birmingham, Eng., water works total of six reservoirs	2.34	43	98 to 128	...	4,460	20,838
All Boston water works reservoirs combined	5.82	14	14 to 65	...	.....	15,867
Vyrnwy, Liverpool, Eng	1.75	..	84	129	1,350	14,560
Ware River, Mass	1.62	33	71	...	785	11,190
Sodon, N. Y	.....	..	72	89	500	9,500
Hemet, San Jacinta, Cal	...	..	150	...	200	8,500
Reservoir No. 5, Boston water works	1.91	19	65	70	1,865	7,438
Titicus, N. Y	.....	..	105	115	.....	7,000
Hobbs Brook, Cambridge water works	1.00	12	23	...	.....	2.500
Cochituate, Boston water works	1.35	8	...	...	.....	2,160
Reservoir No. 6, Boston water works	0.29	25	52	...	1,500	1,500
Furens, France	.....	..	146	184	.....	422

Note.—The heights of dams are given from the ground and rock up to the level of full reservoirs. The lengths of dams are the distances across the valleys at the level of full reservoirs on the line of the main dam. The capacities are given in United States gallons.

As the time is so limited I will not detain you with too many statistics, but will merely call your attention to some of the more interesting features which are shown by the tables and diagrams herewith presented.

In Table II. are shown the estimated populations of the Metropolitan district by five year periods up to 1930, and the estimated consumption of water. The increase in the consumption of water during recent years has been much more rapid than the increase in population, owing in part to the introduction of a greater number of fixtures, allowing more leakage, and in part to the greater demands for water for manufacturing purposes.

TABLE II.

ESTIMATED POPULATION AND CONSUMPTION OF WATER IN METROPOLITAN DISTRICT FOR EACH FIVE YEARS FROM 1895 TO 1930.

Year.	Estimated Population.	Daily Consumption per Inhabitant, Gallons.	Total Daily Consumption, Gallons.
1895...........	984,301	85	84,000,000
1900............	1,148,033	90	103,000,000
1905.......... ..	1,328,787	94	125,000,000
1910............	1,526,623	97	148,000,000
1915............	1,743,510	99	173,000,000
1920............	1,979,930	100	198,000,000
1925............	2,238,500	100	224,000,000
1930...........	2,521,875	100	252,000,000

Plate II. shows the cross section of the dam at the Nashua basin and corresponding sections of certain other notable dams drawn on the same scale. This shows how advantageous a point has been selected and how small the dam is in comparison with the other dams in proportion to the quantity of water stored. Fig. 3 shows on a larger scale a cross section of the Nashua dam in greater detail.

The general location of the dam with reference to the Metropolitan district is shown by Plate I., which also shows the aqueduct which will be constructed to carry the water to basin No. 5 of the present Boston water works on the upper section of the Sudbury watershed, from which point it will flow through existing aqueducts to Chestnut Hill reservoir for the present. When the capacity of these aqueducts is exceeded an additional aqueduct will be con-

structed to Spot Pond, as shown by the map. The aqueducts now in use are shown by dotted lines, and those to be constructed by solid black lines.

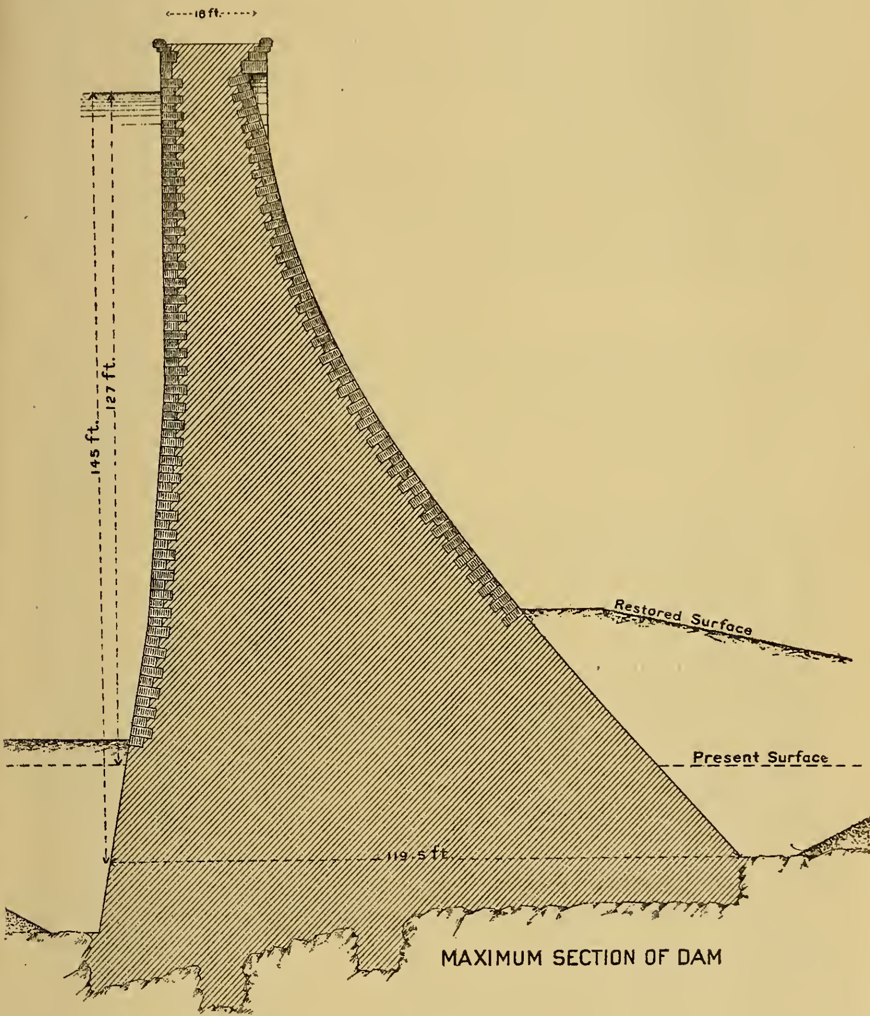


Fig. 3.

The first addition to the supply will be made by adding a portion of the Assabet river watershed. The next addition will be made by constructing an aqueduct from the Upper Ware to the Nashua river,

and a reservoir can be constructed which will still further increase the supply. With the addition of the Assabet the available supply is estimated at 201,000,000 gallons, and with the Upper Ware at 272,000,000 gallons daily, and at some time in the future when it has become necessary to add the Lower Ware and the Swift rivers to the supply, the estimated capacity will be 472,000,000 gallons per day, with the Deerfield river still to the westward and capable of being added if required.

Table III. shows the various watersheds investigated and some others for comparison, with their populations per square mile and the colors of the waters obtained from them, and also the relative hardness of the various waters.

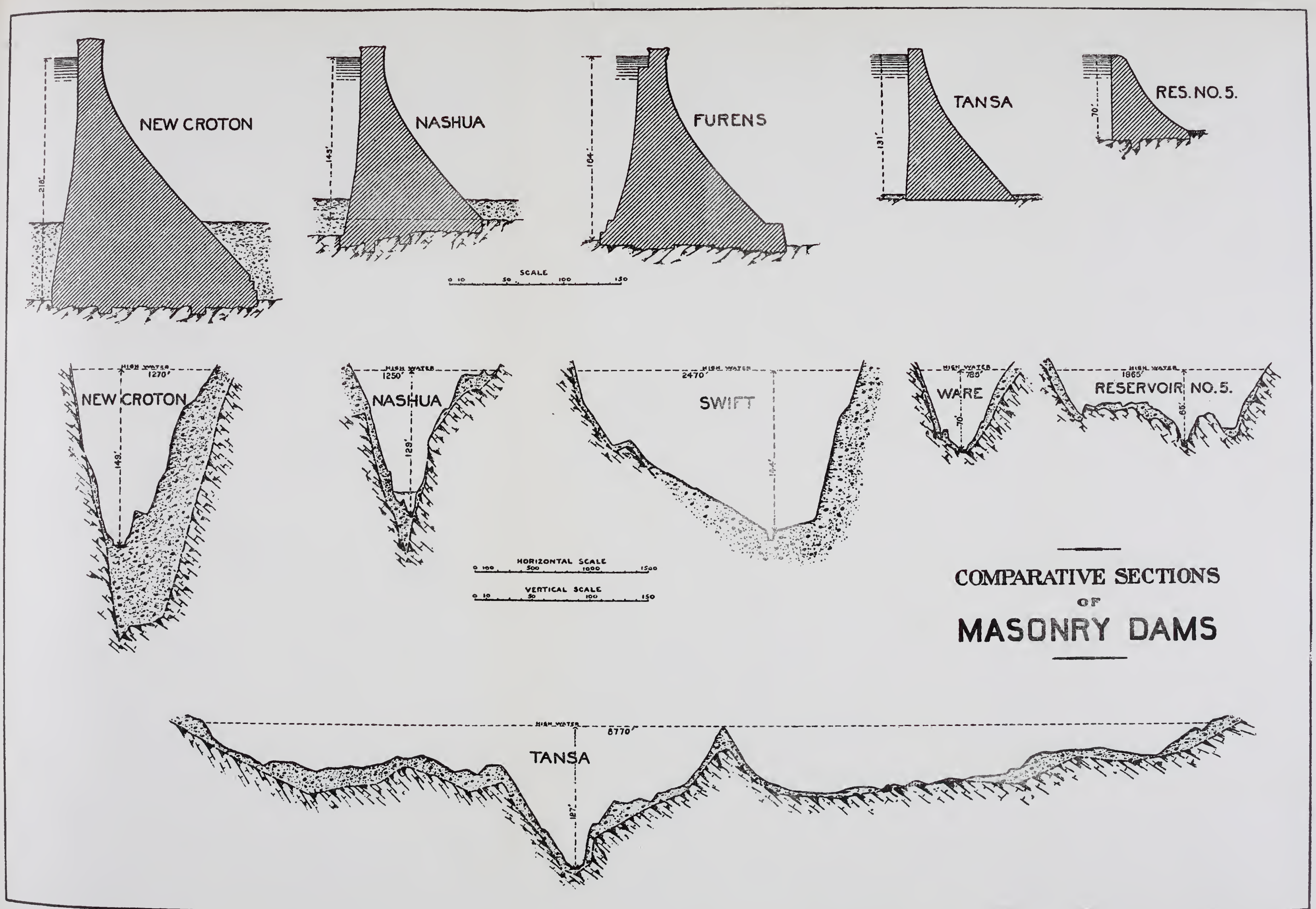
TABLE III.

TABLE SHOWING THE AVERAGE HARDNESS AND COLORS OF WATERS AND THE POPULATION PER SQUARE MILE UPON CERTAIN WATERSHEDS.

	Hardness.	Color.	Population per Square Mile. (1894.)
Deerfield River above Shelburne Falls	1.5	0.40	21
Swift River at Belchertown	0 8	0.38	30
Ware River at Cold Brook	0.7	0.75	32
Lake Winnipiseogee	1.3	0.01	35
Assawompsett Pond	0.6	0.28	36
Tributaries of Assabet River	1.6	0.36	60
Nashua River above Clinton	**1.1**	**0.40**	**69**
Ipswich River at Danvers	1.7	1.36	72
Stony Brook at Cambridge dam	2.1	0.71	107
Shawsheen River at Old Middlesex Canal crossing	1.8	0.89	123
Charles River above South Natick	1.4	0.86	179
Sudbury River	1.5	0.87	376–165
Lake Cochituate	2.0	0.22	770–185
Saugus River at Howletts dam	3.5	1.16	709
Upper Mystic Lake	5.2	0.11	984

NOTE.—Where two figures are given for population per square mile, the first is the total population and the second is the population remaining after deducting the districts from which the sewage has already been or is soon to be diverted to a point outside the watershed.

It will be seen that the Nashua river watershed has a population of 69 persons to the square mile, and the water from it has a color of 0.4 and a hardness of 1.1, and it will be seen that, as indicated by the color and hardness, it is an exceptionally good water. The complete analyses show that the water is in every way up to these



Heliotype Printing Co., Boston.

indications, and it is expected that with the long storage in the reservoir the color will be greatly reduced so that the water will be almost colorless, as is the water in Lake Winnipiseogee, which is so often mentioned as an exceptionally good water.

In Table IV. are given some statistics relating to the Nashua river watershed and reservoir. The destruction of town, railroad, and mill property will be unprecedented. The greater part of the small manufacturing village of West Boylston, and the whole of the smaller village of Boylston, will be flooded as will the lower parts of the village of Oakdale.

TABLE IV.

STATISTICS RELATING TO NASHUA RIVER WATERSHED.

Area of watershed, square miles	118.23
Population upon watershed	8,188
Villages with populations of over 100	10
Population of these villages	4,446
Farming and scattered population	3,742
Area of swamps, square miles	3.63
Area of existing ponds and reservoirs	2.19

STATISTICS RELATING TO NASHUA RIVER RESERVOIR.

Estimated cost	$9,105,000
Area of water surface, square miles	6.56
Capacity, gallons	63,068,000,000
Length, miles	8.41
Maximum width, miles	2.05
Shore line, excluding islands	35.4
Maximum depth, feet	129
Average depth, feet	46
Length of railroad flooded, miles	6.56
Length of road flooded, miles	19.21
Dwellings in flooded area	224
Inhabitants in flooded area	1,711
Mills within reservoir	6
Churches	4
School houses	6
Time required to fill reservoir, years (about)	1.5

Notwithstanding all of the costs for damages involved in destroying these manufacturing villages and the large cost of removing the soil and organic material to make a perfectly clean and sanitary basin, Table V. shows that the relative cost reduced to million gallons of water stored is quite low, less than in the various reservoirs which have been constructed in the vicinity of Boston. Thus the cost per million gallons in the Nashua river reservoir will be $144, as against $400 in Hobbs Brook reservoir, and $336 in reservoir No. 5.

TABLE V.

Cost per Million Gallons of Water Stored.

City.	Name of Reservoir.	Acres Flowed.	Storage in Million Gallons.	Cost per Million Gallons.
Boston............	Reservoir No. 1	143	280	$918
Boston......	Reservoir No. 2	134	530	879
Boston............	Reservoir No. 3	253	1,080	388
Boston	Reservoir No. 4	167	1,400	581
Boston............	Reservoir No. 5	185	1,530	566
Boston............	Reservoir No. 6	1,220	7,438	336*
Cambridge........	Proposed reservoir on Hobbs Brook†	350	1,500	400
Greater Boston....	Proposed reservoir on Nashua River	4,195	63,068	144

It is estimated that 1898 when, under favorable circumstances, the first supply of water can be obtained from the Nashua river, the consumption of water in the district will be about 100,000,000 gallons, and as the capacity of the present source in a dry year is only estimated at 83,000,000 gallons, it will be seen that the work of obtaining a new supply was begun none too soon.

It is proposed that the Metropolitan Water Board shall take charge of the distribution of water to the various cities and towns. At first the water will all be brought to Chestnut Hill reservoir. From this point a small part of it will be pumped by a low-lift pump to Spot Pond, which will act as a distributing reservoir for the northern part of the district. It is now used as a source of supply for the town of Melrose and the cities of Malden and Medford jointly. A high service station will be located near Spot Pond for pumping to the higher portions of the northern part of the district. As mentioned above, when the capacity of the aqueducts leading to Chestnut Hill reservoir is reached, an additional aqueduct will be built leading directly to Spot Pond.

The strongest evidence of the care and judgment used in perfecting the plans is furnished by the fact that not a word of criticism of any engineering feature of the plans has been advanced by any engineer or superintendent of the various municipalities in the

*Based upon estimated cost of reservoir.

†The figures for this reservoir are based upon preliminary estimates of cost and capacfty, as given in the annual report of the Cambridge Water Board for 1893.

CROSS SECTIONS
OF THE PROPOSED
NASHUA-SUDBURY AQUEDUCT

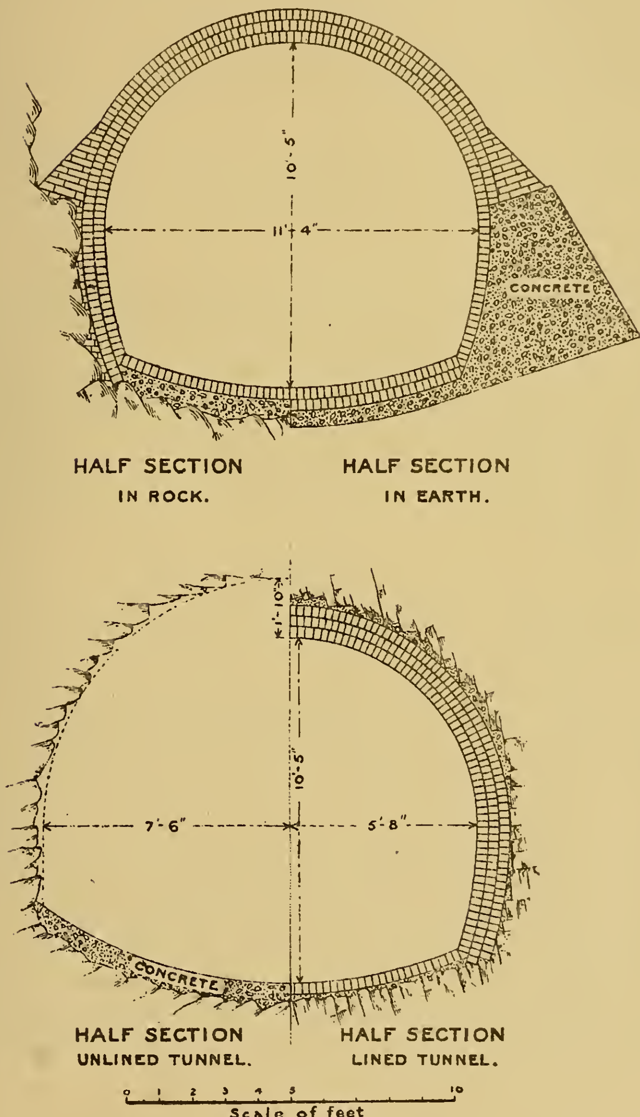


FIG. 4.

district. It has commended itself to all, as being not only a plan which will meet all the requirements, but as having been so carefully considered there is every reason to believe that it is the best one, and the cities that have objected to being included in the Metropolitan district have based their objections upon the cost of the work and the fact that they believed their present supplies were sufficient for their immediate needs, and they were unwilling to meet at the present time the expense of providing water for themselves at a much later date. It is also very gratifying to the originators of the project that the General Court has met the question squarely, and has created a water board to carry out the project, and one of our members, Mr. John R. Freeman, has been given a place upon the board with Mr. Stearns as chief engineer, and Mr. Brackett, until today our senior editor, as engineer in charge of the Department of Distribution.

A word should be said in acknowledgement of credit which is due to the members of the Massachusetts State Board of Health for their consideration of the questions. While Mr. Stearns has had charge of them, he has always had the support and wise advice of the members of that board, and I can assure you from my close acquaintance with them and with the details of their work, that their advice has gone a long way towards the successful carrying out of this plan.

DISCUSSION.

The President. Mr. Noyes would be glad to answer any question any member would like to ask.

Mr. Cairns. I wish Mr. Noyes would tell us in a word or two how the cost of this work is to be distributed and borne.

Mr. Noyes. The work is paid for by the proceeds from the sale of bonds of which $27,000,000 are authorized. The bonds are payable in not less than 30 nor more than 40 years, and the interest on them and the contributions to the sinking fund necessary to pay them at maturity and the operating expenses for each year are added together by the treasurer and distributed as follows:

Boston pays that proportion of the whole amount that the valuation of Boston bears to the valuation of all the property in the district. The remainder is distributed among the remaining cities and towns, one-third in proportion to their respective valuations, and

two-thirds in proportion to their respective populations, but with this exception, that the cities and towns in the Metropolitan district which have not yet reached the safe capacity of their works in a dry year and have not applied for or received water from the Metropolitan Water Board, pay only one-sixth as much proportionately as the other cities and towns, that is to say, until they need the water, for the purpose of this calculation, their populations and valuations are taken at only one-sixth of the actual, while the other cities and towns are reckoned upon their full populations and valuations.

Mr. Cairns. What becomes of the present sources?

Mr. Noyes. The present sources will be utilized so far as that can be done, but many of them ought to be abandoned at the present time, and would be if other sources were available. Boston's principal sources are to be taken by the Metropolitan Water Board for the benefit of the whole district. It will be found gradually that the other sources cannot be maintained, either from sanitary reasons or from an economical standpoint, and they will gradually be abandoned. But for the most part they are very insignificant, and although they have, up to the present time, fairly well supplied the district, yet the district is fast outgrowing them.

Mr. Cairns. Are any of these places supplied by private companies.

Mr. Noyes. Yes; some four or five of them are at the present time so supplied. One of the companies has signified its perfect willingness to give the town a bond to pay all of the cost that would be assessed on the town for a supply. The other municipalities are taking steps towards purchasing the works, so it is anticipated that, with possibly one or two exceptions, there will be no supply in the Metropolitan district operated by a private company.

STATISTICS

FOR

The Year 1894.

IN FORM ADOPTED BY THE

New England Water Works

ASSOCIATION.

TABLE I. —GENERAL AND PUMPING.

TABLE II. —FINANCIAL.

TABLE III.—CONSUMPTION.

TABLE IV.—DISTRIBUTION—MAIN PIPE.

TABLE V. —DISTRIBUTION—SERVICE PIPE.

Compiled by the
JUNIOR EDITOR,
New London, Conn.

TABLE I.—GENERAL AND PUMPING.

					1.	2.		
Number.	Name of City or Town.	Date of Construction.	Source of Supply.	Mode of Supply.	Builders of Pumping Machinery.	Kind of Fuel.	Per Cent. Ashes.	Price Per 2,240 lbs.
1	Attleboro, Mass...	1873	Well	Pump to S. P.	Blake and Deane	Bituminous		$ 4.60
2	Bay City, Mich. ..	1872	Lake Huron	Pump Direct	Holly	Coal and Pine		
3	Boston, (Cochitu'e)	1848	Lake Cochituate and Sudbury River	Gravity and Pump to Reservoir	Holly and Quintard	Bituminous	7.4	4.40 to 4.52
4	Boston, (Mystic)..	1864	Mystic Lake	Pump to Reservoir	Worthington	Bituminous	11.2	3.75 to 5.25
5	Brockton, Mass...	1880	Reservoir	Pump to Stand P.	Worthington	Bit. and Anth.	9.7	4.76 to 6.45
6	Burlington, Vt....	1868	Lake Champlain	Pump to Reservoir	Worthington	Anth and Shav		5.09 to 5.95 & 38.50 per wk.
7	Fall River, Mass..	1874	Watuppa Lake	Pump to Stand P.	Worthington and Davidson	Bituminous		
8	Fitchburg, Mass...	1872	Storage Reservoir	Gravity				
9	Lynn, Mass.......	1872	Storage Reservoir	Pump to Reservoir	Leavitt and Loretz	Bituminous		3.65 to 4.50
10	New Bedford, Mass	1869	Storage Reservoir	Pump to Reservoir	McAlpine, Worthington and Worthington H. D.	Bit. and Anth.	8.0 12.0 16.0	4.20 to 5.00
11	New London, Conn	1872	Lake Konomoc	Gravity				
12	Newton, Mass.....	1876	Filter basin and wells	Pump to Reservoir	Blake and Worthington	Bituminous	6.0	4.13
13	Oberlin, Ohio.....	1887	Vermillion River	Pump to Stand P.	Deane	Bituminous		2.35 to 2.50
14	Plymouth, Mass...	1855	Ponds	Gravity and Pump.	Worthington	Bituminous		4.25
15	Springfield, Mass..	1864	Storage Reservoir	Gravity				
16	Taunton, Mass....	1876	Elders Pond	Pump Direct	Holly and Allis	Bituminous	8.28 .42	3.85 4.20
17	Waltham, Mass. ..	1873	Filter Basin	Pump to Reservoir	Worthington	Cumberland	15.0	4.87 to 5.75
18	Woonsocket, R. I..	1884	Crookfall Brook	Pump to Tank	Worthingt'n and Deane	Bituminous	7.6	4.35
19	Yonkers, N. Y.....	1876	Storage Reservoir	Pump to Reservoir and S. P.	Wright and Worthington	Anthracite	12.8	5.09

TABLE I.—GENERAL AND PUMPING.—Continued.

Number.	3. Coal Consumed for the Year, lbs.	4. Lbs. of Wood. 3.	5. Total Fuel for Year, lbs.	6. Total Pumpage for Year. Gallons.	7. Average Static Head on Pumps.	8. Average Dynamic Head on Pumps.	9. Gallons Pumped per lb. of Coal.	10. Foot lbs. per 100 lbs. of Coal, no Deductions.	11. Cost per Mil. Gals. Pum'd. Pump'g Station Expen.	12. Cost per Mil. Gals. 1 foot High. Pump'g Station Expen.	13. Cost per Mil. Gals. Pumped. Total Mainte'e.	14. Cost per Mil. Gals. 1 ft. High. Total Mainte'e.
1	451,050	1,000	452,050	99,136,440	160.0	175.0 188.0	219.8	34,385,136	$ 18.76	$ .10	$ 145.87	$ .775
2				1,024,735,621		113.0			7.29	.064	44.39	.393
3	4,637,660			3,795,830,595		126.1	818.6	86,459,300	6.62	.052		
4	8,763,800			3,751,418,700		148.6	428.1	53,057,500	8.77	.059		
5	494,707	225	494,932	314,854,473		43.0	636.0	22,813,863	8.59	.199	99.11	2.30
6				336,504,725	289.0	316.0			23.59	.074	128.04	.405
7	2,994,880			889,954,187		185.8	297.1		12.56		148.44	
8												
9	454,400 1,426,800	200 900	454,600 1,427,700	363,138,230 1,105,150,200		160.5 159.8	798.8 774 7	106,966,048 103,176,674	6.29	3.93	84.86	.529
10	1,000,995 305,800 1,225,600	33 133 540	1,001,028 305,933 1,225,780	649,615,574 157,965,580 959,810,926	125 8 125.8 125.2	135.1 127.0 127 5	649.0 516.0 783.0	73,097,580 54,694,053 83,295,142	6.74	5.18	30.66	.235
11												
12	1,585,100	10,000	1,595,071	597,591,100	234 0	260 0	374.0	82,536,000	12.70	.049	170.67	.66
13	237,780			25,234,000	70 0	70.0	107.0	6,220,000	45.71	.653	156.56	2.23
14	248,880		248,880	109,248,480	65.0	66 0	448.2	24,670,170	14.26	.216	90.98	1.38
15												
16	771,800 224,350			400,836,270		108.09	519.8	46,818,102	11.62	.107	140.29	1.39
17	1,728,700			452,227,087	164.0	190.0	260.0	41,603,620	19.90	.105	113.48	.60
18	784,159	103	784,262	206,765,840	239 0	240.0	262.0	52,996,254	16.65	.069	132 58	.55
19	25,196 3,600,913	 8,933	25,196 3,601.846	5,959,553 986,053,346	185.0 185 0	196.0 220.0	236.0 274.0	38,663,771 50,230,095	12.54	.057	98.67	.448

TABLE II.—FINANCIAL.

Number.	Name of City or Town.	Receipts from Consumers.				
		A	B	C	D	E
		Rates Domestic.	Rates Manufacturing.	Net Receipts for Water.	Miscellaneous Receipts.	Total Receipts.
		$	$	$	$	$
1	Attleborough, Mass			11,174.60		
2	Bay City, Mich			22,820.83		
5	Brockton, Mass			41,653.56	191.64	41,845.20
6	Burlington, Vt	33,249.10	4,975.74	38,224.84		
7	Fall River, Mass			111,419.57		
8	Fitchburg, Mass	47,229.71	9,402.97	56,632.68		
9	Lynn, Mass	134.306.91	37,143.25	171.450.16	1,781.57	173,231.73
10	New Bedford, Mass	76,677.46	6,838.73	83,516.19	162.85	83,679.04
11	New London, Conn			38,634.05		
12	Newton, Mass	71,170.65	6,800.00	77,970 65	4,332.50	82,303.21
13	Oberlin, Ohio	2,858.00	320.15	3,178.50		
14	Plymouth, Mass	16,373.89	1,568.64	17,942.53	451.78	18,594.31
15	Springfield, Mass			158,461.46	24,430.29	182,891.75
16	Taunton, Mass	37,257.38	10,068.28	47,325.66	795.18	48,120.84
17	Waltham, Mass	48,679.75	5,110.65	53,790.40	14.073.52	
18	Woonsocket, R. I	25,318.75	6,342.25	31,661.00	101.11	31.762.11
19	Yonkers, N. Y	70,959.37	25,754.67	96,714.04	2,249.58	98,963.62

TABLE II.—FINANCIAL—Continued.

Number.	Receipts from Public Funds.					K	AA.	BB.	Miscellaneous Expenses.	Total Maintenance.
	F	G	H	I	J					
	Hydrants.	Fountains.	Street Watering.	Public Buildings.	General Appropriation or Miscellaneous.	Gross Receipts.	Management and Repairs.	Interest on Bonds.		
1	$	$	$	$	$ 6,800.00	$ 47,981.50	$ 5,191.38	$ 9,270.00	$	$ 14,461.38
2										16,977.98
5	3,000.00					44,845.20	7,581.38	23,625.66		31,207.04
6	2,960.00			370.00		43,067.99	31,867.12	8,760.00	625.00	41,252.12
7					20,000.00	137,532.39	43,171 81	99,835.00		143,006.81
8							23,287 96			36,987.16
9					50,198.13		47,449.30	77,158.62		124,607.92
10					29,866.67	113,545 71	31,491.02	37,866.67		69,357.69
11						52,509.05	6,709.22	24,540.00		31,249.22
12	14,000.00	1,195.31	2,400.00	1,022.83	890.77	101,812.12	15,995.99	86,000.00	3,771.22	105,767.21
13					2,485.00	5,663.15	1,556.38	2,410.00		3,966.38
14						18,594.31	5,075.59	4,864.00		9,939.59
15	14,340.00	1,802.00	4,308 25	3,883.50	25,000.00	233,105.50	19,437.33	99,500.00	7,358.34	126,295.67
16	3,500.00	1,915.06	800.00	551.93		62,887.83	17,470.53	38,816.50		56,287.03
17	1,482.99			705.50			35,349.55	15,980.00		51,329.55
18	13,832.00	1,110.40	1,639.25	747.07	9,639.58	58,730.41	9,692.46	17,722 04		27,414 50
19	14,390.00					114,653.62	30,934.56	69,283.33		100,217.89

TABLE III.—CONSUMPTION.

Number.	Name of City or Town.	1 Estimated Population. Total at Date.	2 Estimated Population. On Line of Pipe.	3 Estimated Population. Supplied at Date.	5 Quantity used through Domestic Meters—Gals.	6 Quantity used through Man'f'tring Meters—Gals.	Percentage of Total Consumption Metered.	7 Average Daily Consumption Gallons.	8 Gallons Per Day. Each Inhabitant.	9 Gallons Per Day. Each Consumer.	10 Gallons Per Day. Each Tap.
1	Attleborough. Mass.	8,000	6,500	5,000				271,606	34.0	54.0	
2	Bay City, Mich.	33,000	19,500	13,500	52,255,126	52.888,770		2,807,495	83 0	208.0	1,528.0
3	Boston (Coch).	466,500		460,000	4,077,196.000		24.	46,560,000	99.8	101.2	679.2
4	" (Mystic).	117,400		116,000	735,110,000		19.6	10,282,100	87.6	88.6	442.1
5	Brockton, Mass.	31,000	27,280	24,800	78,894,500	28,404,750		862,615	27.8	34.7	222.6
6	Burlington, Vt.	15,700	15,700	15,100	63,535,928	30,319,072		921,930	60.0	61.0	325.0
7	Fall River, Mass.	89,576		85,576				2,438,231	27.2	28.4	
8	Fitchburg, Mass.	28,500	25,200	22.300	56,571,000	168,000,000		2,225.000	78.0	90.0	602 0
9	Lynn, Mass.	69,400		66,990	195,716,250			4,020,344		60.0	
10	New Bedford, Mass.	56,000	45,512	44,661	13,590,386	233,494,702		4,786,760	85.0	107.0	616.0
11	New London, Conn.	15,000	14.700	14,000				1,244,320	83.0	89.0	467.0
12	Newton, Mass	29,300	28,900	28,500	215,000.000	89,000,000		1,622,605	55.4	57.0	290.0
13	Oberlin, Ohio	4,500	3,600	1,850	4,197,000	1,123,000	21.	69,000	15.3	37.0	174.7
15	Springfield, Mass.	51,851	45,000	38,500	280.259,913			4,524,510	87.0	117.0	604.0
16	Taunton, Mass	25,448	23,600	23,545	53,106,757	101,417,264		1,099,103	43.0	46.7	293.0
17	Waltham, Mass.	22,000	21,000	20,000	25,208,860			1,238,975	56.3	59.0	414.0
18	Woonsocket, R. I.	25,000	23,000	20,000				563,368	22.5	26.1	325.0
19	Yonkers, N. Y.	36,000	32.000	31,000	242,240,862	346,630,680	61.5	2,623,760	73.0	85.0	800.0

TABLE IV.—DISTRIBUTION—MAIN PIPES.

Number.	Name of City or Town.	1. Kind of Pipe Used.	2. Size of Pipe, Inches.	3. Length Extended During Year, Feet.	4. Length Discontinued During Year, Feet.	5. Total Length in Use, Miles.	6. Cost of Repairs Per Mile.	7. Number of Leaks Per Mile.	8. Length of Pipe Less Than 4 in., Miles.	9. Hydrants. No. Added.	10. Hydrants. Total in Use.	11. Stop Cocks. No. Added.	12. Stop Cocks. Total in Use.	15. Range of Pressure, Lbs.
1	Attleborough, Mass	C. I. & C. L	4 to 16	20,751		28.3	$	0.15		51	221			50 to 62
2	Bay City, Mich . . .	C. I. & Wyckoff	3 to 20	2,258	171	43.	15.59	1.	.6	4	370	7	647	35 to 38
3	Boston, (Coch) .	C. I.	4 to 48	67.320		572.8			1.7	175	6,217	193	6,359	
4	Boston, (Mystic) . .	C. I., W. I. & C. L.	3 to 30	36,432		173.7			4.7	148	1,446	156	2,138	
5	Brockton, Mass . .	C. I., W. I. & C. L.	6 to 30	28,340	6,160	50.	1.74	0.3		32	453	82	467	47 to 56
6	Burlington, Vt . .	C. I., W. I. & C. L.	4 to 24	8,580	7,352	34.9	18.31	1.	2.7	12	187	65	448	70 to 85
7	Fall River, Mass . .	C. I.	6 to 24			74.				41	743	34	748	80
8	Fitchburg, Mass . . .	C. I., W. I. & C. L.	2 to 30	9,722		57.3	7.87		1.5	21	388	21	429	75 to 80
9	Lynn, Mass	C. I. & C. L.	2 to 20	4,006		121.6				10	783	6	920	50 to 65
10	N. Bedford, Mass.	C. I. & C. L.	4 to 30	17,290	4,522	74.6	22.16	10.	1.2	22	607	27	835	29 to 40
11	N. London, Conn.	C. I. & C. L.	4 to 20	7,858		43.1	10.60	7.	2.9	5	198	8	227	45 to 50
12	Newton, Mass	C. I.	4 to 20	22,021		113.5	11.75	.09	2.7	24	760	38	602	84
13	Oberlin, O	C. I.	4 to 12	2,200		7.5	1.22	.13	.3	5	70	2	44	27 to 32
14	Plymouth, Mass . .	W. I. & C. L.	2 to 20	1,625		33.4	7.30	1.	9.5	2	105	10	307	
15	Springfield, Mass . .	W. I., C. L. & C. I.	¾ to 36	80,529	5,357	117.2	6.07	.31	41.2	28	717	99	1,307	30 to 35
16	Taunton, Mass	C. I.	4 to 20	7,550		70.5	30.65	9.	1.1	23	681	14	466	45 to 50
17	Waltham, Mass	C. I., W. I. & C. L.	2 to 24	5,577		47.1	11.32	.8		12	262	41	585	55
18	Woonsocket, R. I . .	C. I.	4 to 20	13,992	1,103	40.2	3.38	.65	0	25	457	18	387	90 to 115
19	Yonkers, N. Y. . .	C. I.	4 to 30	12,076		49.8	12.59	1.	0	10	523	21	329	

TABLE V.—DISTRIBUTION—SERVICE PIPES.

		16	17	18	19	20	21	22	23	24	25	26a	26b	27	28
		Service Pipe.					Service Taps.				Meters.			Motors and Elevators.	
												Now in Use.			
Number.	Name of City or Town.	Kind of Pipe Used.	Size of Pipe. Inches.	Length Extended. Feet.	Length Discontinued. Feet.	Length in Use. Miles.	No. Added.	Total in Use.	Av. Length of Service.	Av. Cost of Service.	Number Added.	Domestic.	Manu-fac'ing.	No. Added.	Total in Use.
1	Attleborough, Mass									$	83	599		1	1
2	Bay City, Mich....	Lead, W. I. and Wood.	3/8 to 8				44	1,837			57	516			
3	Boston, (Coch)....	Lead.	5/8 to 6	49,841			1,970	68,556			291	4,337			540
4	" (Mystic)...	Lead and W. I.	1/2 to 4	18,436			859	23.257			33	494			21
5	Brockton, Mass...	C. I., W. I. and C. L.	1 to 6	4,849	71	17 6	22[illegible]	3,874	22.1	9 37	241	2.478			
6	Burlington, Vt .	Lead and Gal. I.	1/2 to 6	2,794	56	15.3	98	2,835	28	10.00	206	1,008	75	9	26
7	Fall River, Mass..	Lead.	1/2 to 2				345	6,138			359	4.887			
8	Fitchburg, Mass..	W. I., C. L. and C. I.	3/4 to 8	8,186		41.5	162	3,736	58	14.06	151	1,432	115	4	55
9	Lynn, Mass.	W. I., C. L. and Gal.	3/4 to 10	16,305	3,140	87.0	318	10.827			221	890			
10	New Bedford Mass	Lead and C I.	1/2 to 8	8,673	563	48.1	236	7,767	33	8.93	49	163	59	37	68
11	New London, Ct...	Lead, Gal. C. L. & C. I.	1/2 to 4	2,408		9.7	108	2 663	22 3	10.85	9	167			22
12	Newton, Mass.....	Lead, W. I. and C. I.	1/2 to 6	16,046		64.1	305	5,586	60.9	13.59	456	4,224	23		16
13	Oberlin. Ohio.	Gal. and Lead.	3/4				72	399	25	8.00	31	97	5	0	0
14	Plymouth, Mass...	Lead and C. L.	1/2 to 1	315		5 5	37	1,578	18.5	4.28					1
15	Springfield. Mass..	W. I., Tar, Gal. & C. I.	1/2 to 6				482	7.482			269	1.947		2	144
16	Taunton, Mass ...	C. L.	3/4 to 3	5.438	5,108	36.2	124	3.751		11.68	80	1,176	134		13
17	Waltham, Mass...	C. I. and C. L.	3/4 to 6	4,560	974	33.2	52	2,990	81	25.37			75		11
18	Woonsocket, R. I..	Lead and Iron.	5/8 to 6	1.667			110	1,667	15.1	12.24	87	1,386	41	1	6
19	Yonkers, N. Y.. ..	Lead and C. I.	3/8 to 8				213	3,504			234	3,371	111		8

OBITUARY.

HORACE L. EATON.—City Engineer of Somerville, Mass. Died November 23d, 1895. Joined this Association February 13th, 1889.

Mr. Eaton was a native of Boston, and was educated in the Boston public schools, and for many years was employed by the city in connection with the City Engineer's office. From 1870 to 1872 he was employed upon the high service water supply of Roxbury; upon surveys for water supply for Deer Island; upon the construction of the Chestnut Hill Reservoir for the Boston Water Works; the Atlantic Avenue sea wall; high service water supply for South Boston and Dorchester, and other works. In 1873 he was employed upon the construction of the Parker Hill Reservoir. In 1874 he was in charge of field work in connection with the Malden bridge, and in 1875 to 1876 he was in charge of preliminary surveys for the Mystic Valley sewer and on plans for bridges on Massachusetts avenue and Central street. In 1877 and 1878 he was employed upon the construction of the Mystic Valley sewer. From 1884 to 1887 he was engineer in the work of developing the Arnold Aboretum and Franklin and Wood Island Parks, and other similar work. In 1887 he was appointed City Engineer of Somerville, which position he has held up to the date of his death. He was a member of the American Society of Civil Engineers, and of the Boston Society of Civil Engineers, and was secretary of the latter for five years following 1882.

During November, 1895, an investigation of his department was commenced by the City Council, and although the investigation had hardly commenced, and nothing of importance derogatory to the conduct of his office had been developed, the fact that his integrity had been questioned preyed upon his mind and led to the cause of his death.

Mr. Eaton was noted for the thoroughness of his work, and was respected by a large circle of associates.

CORNELIUS F. DOHERTY.—Boston, Mass. Died November 17th, 1895. Joined this Association February 16th, 1894.

Mr. Doherty was employed in the service department of the Boston Water Works from 1883 to 1892, and was Water Registrar of the City of Boston from 1892 to July 1st, 1895.

FRED. I. CHAFFEE.—Superintendent of the East Providence Water Company, East Providence Centre, R. I. Died November 28th, 1895, aged 40 years. Joined this Association December 14th, 1892.

Mr. Chaffee was Superintendent of the East Providence Fire District, and the plant now owned by the Water Company was built under his direction. He has occupied many positions of responsibility, among which was postmaster and State constable.

Table of Contents.

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. X. March, 1896. No. 3.

This Association, as a body, is not responsible for the statements or opinions of any of its members.

QUARTERLY MEETING.

YOUNG'S HOTEL, BOSTON, MASS., Dec. 11th, 1895.

The following members and guests were present, Vice-President Charles K. Walker of Manchester, N. H., presiding:

MEMBERS.

E. L. Abbott, Boston, Mass.; C. H. Baldwin, Boston, Mass.; G. E. Batchelder, Worcester, Mass.; Joseph E. Beals, Middleboro, Mass.; J. F. Bigelow, Marlboro, Mass.; Dexter Brackett, Boston, Mass.; Henry Chandler, Manchester, N. H., Geo. F. Chace, Taunton, Mass.; John C. Chase, Wilmington, N. C.; Harry W. Clark, Lawrence, Mass.; Freeman C. Coffin, Boston, Mass.; R. C. P. Coggeshall, New Bedford, Mass.; H. W. Conant, Gardner, Mass.: Byron I. Cook, Woonsocket, R. I.; Henry A. Cook, Salem, Mass.; F. H. Crandall. Burlington, Vt.; Geo. K. Crandall, New London, Conn.; Geo. E. Crowell, Brattleboro, Vt.; L. E. Daboll, New London, Conn.; Francis W. Dean, Boston, Mass.; John W. Ellis, Woonsocket, R. I.; B. R. Felton, Marlboro, Mass.; F. F. Forbes, Brookline, Mass.; Richard J. Flinn, Brookline, Mass.; Frank L. Fuller, Boston, Mass.; Julius C. Gilbert, Whitman, Mass.; D. H. Gilderson, Bradford, Mass.; Fred B. Gleason, Marlboro, Mass.; E. H. Gowing, Boston, Mass.; E. A. W. Hammatt, Boston, Mass.; Geo. W. Harrington, Wakefield, Mass.; John C. Haskell, Lynn, Mass.; L. M. Hastings, Cambridge, Mass.; V. C. Hastings, Concord, N. H.; William E. Hawks, Bennington, Vt.; Allen Hazen, Boston, Mass.; Horace G. Holden, Nashua, N. H.; Daniel D. Jackson, Newton, Mass.; Willard Kent, Woonsocket, R. I.; Patrick Kieran, Fall River, Mass.; James W. Locke, Brockton, Mass.; T. H. Mackenzie, Southington, Conn.; Wm. McNally, Marlboro, Mass.; James W. Morse, Natick, Mass.; H. H. Nash, Jr., Boston, Mass.; F. L. Northrop, Milford, Mass.; F. G. Perry, Pawtucket, R. I.; W. H. Richards, New London, Conn.; G. J. Ries, Weymouth Centre, Mass.; W. W. Robertson, Fall River, Mass.; H. W. Rogers, Haverhill, Mass.; A. H. Salisbury, Lawrence, Mass.; Sidney Smith, Rutland, Vt.; F. H. Shepard, Derry, N. H.; G. A. Stacy, Marlboro, Mass.; Chas. H. Swan, Boston, Mass.; Lucian A. Taylor, Boston, Mass.; Robert J. Thomas, Lowell, Mass.; Wm. H. Thomas, Hingham, Mass.; W. H. Vaughn, Wellesley Hills, Mass.;

C. K. Walker, Manchester, N. H.; Joseph Watters, Fall River, Mass.; G. C. Whipple, Brighton, Mass.; J. C. Whitney, West Newton, Mass.; Geo. E. Winslow, Waltham, Mass.; E. T. Wiswall, West Newton, Mass.; W. G. Zick, New York City.; Morris Knowles, Boston, Mass.; E. R. Jones, Boston, Mass.; *Engineering Record*, New York City, by C. J. Underwood, Jr.; Chapman Valve Manufacturing Co., Indian Orchard, Mass., by E. L. Ross; Hersey Manufacturing Co., South Boston, Mass., by Samuel Harrison; Henry F. Jenks, Pawtucket, R. I.; McNeal Pipe and Foundry Co., Burlington, N. J.. by Wilmer Reed; National Meter Co., New York City, by J. G. Lufkin; Neptune Meter Co., New York City, by W. G. Zick; Peet Valve Co., Boston, Mass., by Secretary Russell and S. B. Adams; Thomson Meter Co., Brooklyn, N. Y., by E. L. Abbott; Union Water Meter Co., Worcester, Mass., by J. P. K. Otis and Geo. H. Carr; Walworth Manufacturing Co., Boston, Mass., by J. H. Eustis; H. R. Worthington, South Brooklyn, N. Y., by J. M. Betton and Geo. B. Ferguson.

GUESTS.

Gerald Bliss, Walpole, Mass.; M. N. Boardman, Georgetown, Mass.; Arthur N. Cram, Water Commissioner, Walpole, Mass.; J. W. Crawford, Secretary Water Board, Lowell, Mass.; Allston H. Evans, Water Commissioner, Medford, Mass.; William L. Hills, Water Commissioner, Lowell, Mass., Stephen H. Jones, Water Commissioner, Lowell, Mass.; J. J. Moore, Contractor, Boston, Mass.; A. D. Negus, Pumping Engineer, New Bedford, Mass.: Henry P. Plimpton, Chairman Water Board, Walpole, Mass.; Geo. E. Putnam, President Water Board, Lowell, Mass.; Frank L. Weaver, Water Commissioner, Lowell, Mass.

The following new members were elected:

RESIDENT ACTIVE.

E. W. Bailey, Assistant City Engineer, Somerville, Mass.
H. N. Turner, Manager Water Co., St. Johnsbury, Vt.
Arthur Elliott Hatch, Civil Engineer, Providence, R. I.

NON-RESIDENT ACTIVE.

Wm. P. Mason, Professor Polytechnic Institute, Troy, N. Y.
Wm. H. Ashwell, Civil Engineer, Detroit, Mich.

ASSOCIATE.

Mellen S. Harlow, Agent Ingersoll-Sergeant Drill Co., manufacturers Pohle Air Lift Pump, Boston, Mass.

Lester E. Wood, Eastern Sales Agent Anniston Pipe and Foundry Co., and Chattanooga Foundry and Pipe Works.

Mr. Dean of Boston read a paper prepared by Mr. Charles A. Hague of New York on "Operation of a Pumping Plant by Electricity," and also a discussion of the paper which had been presented by Mr. George H. Barrus of Boston. The paper was also discussed by Mr. Dean himself.

COATING OF CAST IRON PIPE.

Mr. Walker. If there is to be no further discussion of Mr. Hague's paper, I would like to ask for a little information as to why it is that cast iron pipe is not coated as well as it was some years ago. I would like to know whether it is because the coating cannot now be obtained, or whether there is some other reason. The pipe should be dipped in tar, and I would willingly pay two or three dollars more a ton for it than for the painted pipe that we usually get now.

An Associate Member stated in reply to Mr. Walker's question, that there was a concern in Philadelphia that had a monoply of the coal tar production, and that it is difficult at times to get distilled tar for coating pipes, and that when it is impossible to get tar which has had the naphtha removed from it by distillation, it is necessary to purchase what can be obtained on the market. He further stated that some of the pipe manufacturers are considering the matter of putting in plants to distill their own tar, and he thought that the day was not far distant when they would be independent and would distill their own tar from the product obtained from the gas works. He further stated that he thought that skilful laborers could apply the crude tar in such a way as to produce almost as good a coating as that obtained with the use of distilled tar.

THE USE OF WATER FROM HYDRANTS.

Mr. Walker. I am very glad to have heard from the gentleman and to learn some of the facts of the case. I didn't come here to be president today, but to ask questions, and I want to know if any of the superintendents here present have had anything to do with skating rinks? Up in Manchester they have a custom of flooding the common and other convenient land. To do this they draw the water from the hydrants, and because the water is not properly shut off, frozen hydrants are usually the result, and there is nothing that a fireman likes to talk about so much as a frozen hydrant. I think it would be better to have a separate pipe put in for the purpose of flooding when it is desired, and I would like to know what the rest of you do in similar cases, so that I could tell my people about it; for when a man has been superintendent as long as I have been, it does make any difference what he says, he is called an old crank anyway. I tell our fire department when they find a

frozen hydrant to go to the next one. They are only 250 feet apart, and when they find one frozen all they have to do is to hitch on more hose and go 250 feet farther. That seems easy enough, but still I suppose it won't do.

There is another thing that troubles me, and that is the public watering troughs. The people most interested in having the troughs put in (for the benefit of the public of course) are the stable keepers, and they want them convenient to their stables. They put meters on the services in their houses and stables, and you cannot charge them for the water used in watering their horses, because they drive them up to that trough every night and morning. Now, if anyone can tell me how to get even with such a fellow I should be much obliged.

Mr. Chase. I am a firm believer in the idea that fire hydrants should be invariably reserved for the use for which they were intended, that is, for extinguishing fires, and that they should only be used by the department.

Mr. Haskell. I don't know what the city ordinances are in Manchester, but I think it would take a good deal of responsibility from the superintendent if the firemen were given the control of the hydrants, and if they were held to the exercise of proper supervision over them, as they are in Lynn. In my city nobody except firemen and the superintendent of the water works has any authority to touch a hydrant. The firemen are held responsible if a hydrant is out of order, unless they may have sent word to the superintendent that there was trouble and they wanted repairs made. They go around in the fall, and if they find a leaky hydrant, or anything that they think may have a tendency to cause it to freeze, they notify us, and then the responsibility is on our shoulders to fix it so that there is no danger; and there is no time when I have allowed that responsibility to rest on me more than a day without discharging it. I don't care to be burdened with any such responsibility, and I don't propose to be open to criticism in case a hydrant is out of order or frozen.

Mr. Jones. As I understand it, an honorary member has no right to speak unless he has permission from the chair, but with your permission I would like to say in regard to hydrants freezing that I think our hydrants as a general thing are not deep enough in the ground. There certainly is a point where they wont freeze. It

wouldn't cost but very little to have the hydrants made considerably longer, and I think that that would save a good deal of trouble. Mr. Walker spoke of having the firemen go to the next hydrant in case the first one was frozen, but it occurs to me that a better plan would be to have the fire in a locality where the hydrants are not frozen. (Laughter.)

Mr. Crandall. I think that if Mr. Walker would provide a temporary shelter over his hydrant, and attach a meter, and send a man to watch it, and charge the parties requesting the flooding meter rates for the water, as well as for the time of the attendant, that he would find that he would have no further trouble with skating rinks.

Mr. Thomas. We have had more or less trouble from the use of hydrants by persons without authority. About a year ago there was a fire in the residence of a member of our water board, and it was reported that the nearest hydrant was frozen; but upon investigation it was found that the hydrant was not frozen, but that an inexperienced fireman had tried to open it in the wrong way, and, with the aid of a long handled wrench and two or three men, had succeeded in breaking the spindle, and the matter was thus explained. We allow water to be used from hydrants by anyone, but we always send a man to operate them, and then if anything happens we know it and are responsible for it, and the man sees that it is in order before he leaves it. We also examine all hydrants after every fire. Our hydrants are about five feet in the ground and I have never known of one being frozen. The firemen are put through a course of training in handling them and we do not have the trouble we used to have from their carelessness.

Mr. Walker. What do you do in case a man wants to flush out a sewer that is stopped up?

Mr. Thomas. We charge him four dollars and make him pay in advance.

Mr. Stacey. In Marlboro we have had a rule ever since we commenced operations that the hydrants were exclusively under the control of the water department, and not even a fireman, except in case of fire, was allowed to touch them without permission from the water department. By starting right in the first place and by sticking to it we have succeeded, up to the present time, in controlling our hydrants, so that the responsibility for their condition rests wholly upon the shoulders of the superintendent, although I have

often got myself disliked by the rigid enforcement of the rule. If a party wants to use the hydrants, and there is a real necessity for it, I send a man and charge the party for the time and for the water. After the first of November the hydrants are not allowed to be used even if permission has been previously granted, except, of course, in case of fire. At the beginning of every winter we inspect our hydrants, and do not wait for them to drain out, but pump them dry. Our department responds to alarms just as if it was itself the fire department, and sees that the hydrants are properly taken care of. We had an application for permission to flood a skating rink, and we told the parties that we would sell the water for 50 cents a thousand and 40 cents an hour for a man to tend the hydrant. After they had figured up the cost they concluded that it would not pay, and we have had no more applications.

I believe that hydrants should be held for the purpose for which they were intended. There will be trouble enough with them in any case, and are always liable to freeze however great care is taken of them. I have known a hydrant to freeze up within twenty-four hours of the time it was inspected, but I have never known one to freeze at the bottom or in the connection. The freezing has always come from the filling up of the post with ground water. We find that we have trouble enough with them taking care of them ourselves and we do not care to trust even the fire department.

ADJOURNED MEETING.

YOUNG'S HOTEL, BOSTON, Jan. 8th, 1896.

The following members and guests were present:

ACTIVE.

E. L. Abbott, Boston, Mass.; Frank A. Andrews, Nashua, N. H.; Lewis M. Bancroft, Reading, Mass.; G. E. Batchelder, Worcester, Mass.; J. F. Bigelow, Marlboro, Mass.; George Bowers, Lowell, Mass.; A. W. F. Brown, Fitchburg, Mass; G. A. P. Bucknam, Norwood, Mass.; George F. Chace, Taunton, Mass.; John C. Chase, Wilmington, N. C.; Harry W. Clark, Lawrence, Mass.; R. C. P. Coggeshall, New Bedford, Mass.; Byron I. Cook, Woonsocket, R. I.; B. R. Felton, Boston, Mass.; Desmond FitzGerald, Boston, Mass.; Z. R. Forbes, Brookline, Mass.; Frank L. Fuller, Boston, Mass.; T. C. Gleason, Ware, Mass.;

Albert S. Glover, Boston, Mass.; W. J. Goldthwait, Marblehead, Mass.; J. A. Gould, Boston, Mass.; Richard A. Hale, Lawrence, Mass.; G. W. Harrington, Wakefield, Mass.; John C. Haskell, Lynn, Mass.; Arthur E. Hatch, Providence, R. I.; John S. Hodgson, Wellington, Mass.; Horace G. Holden, Nashua, N. H.; William S. Johnson, Boston, Mass.; George A. Kimball, Boston, Mass.; Horace Kingman, Brockton, Mass.; Morris Knowles, Boston, Mass.; James W. Locke, Brockton, Mass.; Edward C. Nichols, Reading, Mass.; John H. Perkins, Watertown, Mass.; George S. Rice, Boston, Mass.; W. H. Richards, New London, Conn.; G. J. Ries, Weymouth Centre, Mass.; W. W. Robertson, Fall River, Mass.; Harley E. Royce, Brookline, Mass.; A. H. Salisbury, Lawrence, Mass.; William T. Sedgwick, Boston, Mass.; George A. Stacy, Marlboro, Mass.; Lucian A. Taylor, Boston, Mass.; Robert J. Thomas, Lowell, Mass.; William H. Thomas, Hingham, Mass.; W. H. Vaughn, Wellesley Hills, Mass.; C. K. Walker, Manchester, N. H.; J. Alfred Welch, Methuen, Mass.; George C. Whipple, Brookline, Mass.; George E. Winslow, Waltham, Mass.; C. F. Murphy, Marlboro, Mass.; J. C. Whitney, Newton, Mass.; Chadwick Lead Works, Boston, Mass., by A. H. Brodrick; Chapman Valve Manufacturing Co., Indian Orchard, Mass., by E. L. Ross.; Deane Steam Pump Co., Holyoke, Mass., by F. H. Hayes; Hersey Manufacturing Co., Boston, Mass., by Jas. A. Tilden, J. E. Spofford and Samuel Harrison; Ingersoll-Sergeant Co., Boston, Mass., by M. S. Harlow; Ludlow Valve Manufacturing Co., Troy, N. Y., by H. B. Winship; National Meter Co., New York City, by C. H. Baldwin; Peet Valve Co., Boston, Mass., by S. B. Adams; Perrin, Seamans & Co., Boston, Mass., by H. L. Bond; Anthony P. Smith, Newark, N. J., by W. H. Van Winkle; Union Water Meter Co., Worcester, Mass., by J. P. K. Otis; R. D. Wood & Co., Philadelphia, Pa., by Jesse Garrett and A. H. Hoffman; *The Engineering Record*, by C. J. Underwood, Jr.

GUESTS.

M. F. Brennan, Lowell, Mass.; W. R. Copeland, Lawrence, Mass.; J. W. Crawford, Boston, Mass.; Frank S. Hart, Boston, Mass.; S. H. Jones, Lowell, Mass.; M. A. Kimball; Geo. E. Putnam, Lowell, Mass.; Dr. Theobold Smith, Boston, Mass.; Col. W. E. Spaulding, Nashua, N. H.

President FitzGerald on calling the meeting to order, spoke as follows:

Gentlemen of the New England Water Works Association:

This is the first opportunity that I have had of meeting with you since you did me the honor to elect me as your presiding officer. It is perhaps fitting that I should now give expression briefly to a few of the thoughts that are uppermost in my mind. In the first place, I wish to acknowledge my appreciation of the responsibilities of the high office to which I have been elected, and to promise my best efforts to the advancement of the interests of this association. No one can have followed very closely the past history of this body

without recognizing how rapidly it has pushed its way to the front, as one of the leading water works institutions of the country. The New England Water Works Association has not only come to stay but it is going to make its influence felt more and more as time rolls on, in other words, it has a brilliant future awaiting it.

There are two ways in which we may receive the development of this united band of water works officials. We may go on in a conservative way as we have begun, making this society an exchange ground for our ideas and experiences, which was indeed the very corner stone of our foundation. Or we may easily drift into a more formal method of procedure as we expand. For my own part, I believe the latter method would be highly undesirable, and that we should continue for some years to come at any rate, to make these meetings common ground, where the youngest comer to our ranks will be as welcome as the oldest veteran, and where it will be distinctly understood that we come to learn and to have a good time in the learning.

I shall never forget my own indebtedness for valuable ideas in water works construction and management, gathered at various times from the many members who have narrated on this floor in a simple manner, their own experiences. I hope that we shall give an important place in the future as in the past, to the idea of the five minute papers; let us have plenty of them and let no one feel that his own experience is too restricted to be narrated on this floor.

There is one other matter to which I wish to allude before proceeding with the regular order of exercises. We have lately as you know, entered into a mutual arrangement with the Boston Society of Civil Engineers, for the occupancy of headquarters in the new Tremont Temple building. These rooms, I believe under wise management, can be made extremely useful and attractive to the members of both societies. It is my own idea that we should at once begin to form a distinctive water works library. If this plan is entered into with zeal and persistence, it is my belief that in the course of a few years we shall be able to collect here in Boston one of the finest water works libraries in the world. Certainly if you gentlemen enter into this scheme, there is no reason why this cannot be done. For the purpose of starting the matter, in however humble a way, I propose now to give the association the larger part of books and pamphlets on water works subjects that I have collected during the past twenty years. Not that there is any great value attached to

these as a collection, although I believe there are some volumes which could not be duplicated, but I wish to give some visible form to the idea. I have a number of bound volumes of water works reports to which I have always attached more or less importance; if other gentlemen will contribute to the expansion of this collection and to the filling of gaps, and if we can then start a good system for the collection of all water works reports which are issued in the future, this will in itself in the course of time prove of great value to those who are to succeed us in our chosen vocation. But I need not point out the ease with which a library can be collected by the united efforts of our members, nor the advantages which will accrue from a library formed in this way. It seems to me that the matter is one which can be safely left in your hands.

ELECTION OF NEW MEMBERS.

On motion of Mr. Fuller, the secretary cast the ballot of the association for A. O. Doane, assistant engineer in charge of the additional supply for the city of Newton, and for Huber D. Card, city engineer, Willimantic, Conn., applicants for resident active membership, and they were declared elected members.

The President read a communication from Mr. F. A. W. Davis, President of the American Water Works Association, extending an invitation to the members of the New England Water Works Association to be present at the meeting of the American Water Works Association at Indianapolis in May, and he stated that he was anxious to have the New England people largely represented.

On motion of Mr. Holden, a request for a copy of Dr. Smith's paper was referred to the Executive Committee with full powers.

THE PRESIDENT. I suppose there never has been a time, gentlemen, when men were inquiring with so much care and detail into everything connected with water-borne diseases. The fact is, if we are going to be killed by drinking water, we want to know exactly how it is done, and we want to know it from the best possible authority. Dr. Theobold Smith, Pathologist of the Massachusetts State Board of Health, has very kindly come here today to tell us about this subject, and I have the pleasure of introducing him to you now. He will read a paper on "Water-Borne Diseases."

THE WATER SYSTEM OF BURLINGTON, VT.

BY

F. H. Crandall, C. E., Superintendent.

[Read September, 1895.]

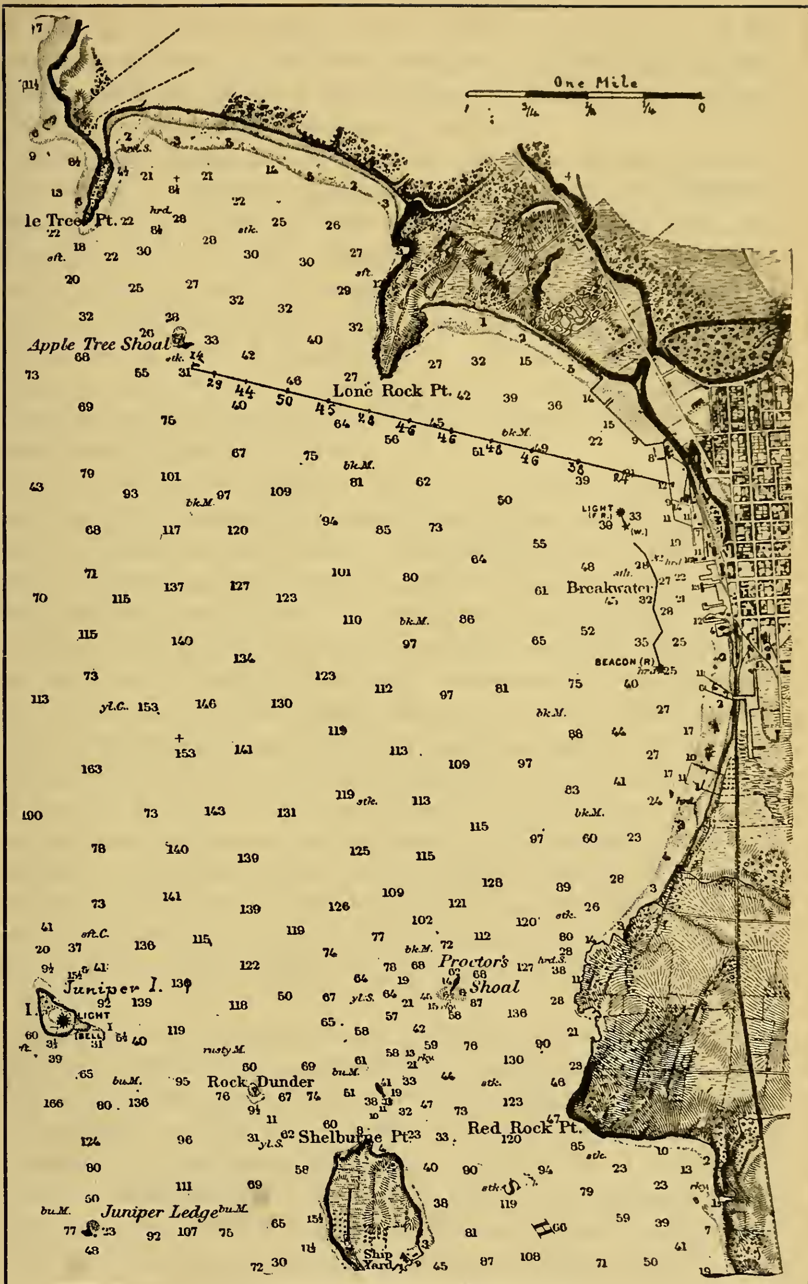
Mr. President and Gentlemen: As it has been suggested that a description of the Burlington works would be appropriate, and lest you should undertake to investigate for yourselves and come to an untimely end in the north railroad yard, I will, with your permission, occupy a few moments in their description.

An act to incorporate the City of Burlington passed the legislature in November, 1864, and was accepted at a town meeting held in January, 1865. On the first day of October of the following year the city came into possession, by purchase, of the plant of the Burlington Aqueduct Company, comprising an underground brick reservoir of about 75,000 gallons capacity, several thousand feet of small cast and wrought iron mains and about two hundred lead services. Lead has since given place to galvanized iron as a material for services.

The reservoir of the Aqueduct Company constructed on the same general plan as the covered reservoirs recently built in Newton and Brookline, was supplied at first from springs higher up the hill.

At the time of the purchase of the works by the city, the gravity supply, some five to fifteen thousand gallons per day was augmented by a pump taking water from Lake Champlain with a maximum capacity of 63,000 gallons daily. The Aqueduct Company made no attempt at fire protection.

The initial appropriation by the city for water works was $150,000. Before a decision was reached as to the most desirable point from which to obtain the city's water supply, a spirited if not acrimonious debate as to the relative merits of lake and river water was indulged in, and the columns of the local papers teemed with all sorts of exaggerations



LOCATION OF INTAKE, BURLINGTON HARBOR.

of the merits and demerits of the different locations, one of the arguments in favor of the river being that at times the proposed location for a lake intake at the north end of the bay was covered with the muddy and filthy waters of the river.

The water committee secured the services of an eminent hydraulic engineer who submitted plans and estimates for four different schemes, three of which contemplated taking water from the Winooski river. He did not hesitate to recommend the river as a source of supply, though he considered that the water from the lake would be of greater purity. His recommendations were accepted, and placed on file. It was decided to use cement lined pipe, not wholly on account of the superiority of the pipe, but, as I gather from the report of Mr. Wm. J. McAlpine, for the purpose of saving about twelve thousand dollars.

However much the judgment of those who were responsible for the laying of the cement pipe, which many of us are today replacing, may be criticized, and however disrespectfully the "old cement pipe" may be regarded today, we are still obliged to admit that in 1867 with cast iron pipe at $75 to $80 per ton and samples of it in the city, which after a few years use could be crushed with the heel for their entire length, there was a reasonable doubt about the relative merits of the two pipes. We are every year replacing more or less small cement pipe with larger cast iron pipe, but even if the original pipe had been cast iron, we should be doing the same thing on account of its size. It may be that in many instances the much despised cement pipe has served its day and generation well, and instead of being our debtor is in reality responsible for a large amount of prosperity. R. D. Wood & Company furnished the cast iron pipe of which there were several thousand feet used and the Patent Water and Gas Pipe Company furnished and laid the cement lined pipe.

An open earthwork reservoir of 2,236,000 gallons capacity, with slopes paved with cobbles and the bottom covered with sand, was built for about nine thousand dollars. The embankment was constructed of unselected material without rolling or puddling, and was allowed to settle for a year before being subjected to the pressure of a full reservoir. On the 25th of December, 1867, a Worthington pump with a capacity of 750,000 gallons daily first pumped water through 8,362 feet of ten inch pipe, into the reservoir, against a static head

of 125 pounds. Water is pumped directly into the distributing mains, the surplus going to the reservoir.

The pump and the engineer who was then in charge have since that time served the city faithfully and efficiently, celebrating the 27th anniversary of their association together in business in the midst of a conflagration which crumbled brick walls, collapsed cast iron pipes and left of the thickly piled lumber yard on three sides of the station, hardly ruins enough to indicate what it had been. A second three quarter million Worthington pump was the following year added to the plant at an expense of $8,000.

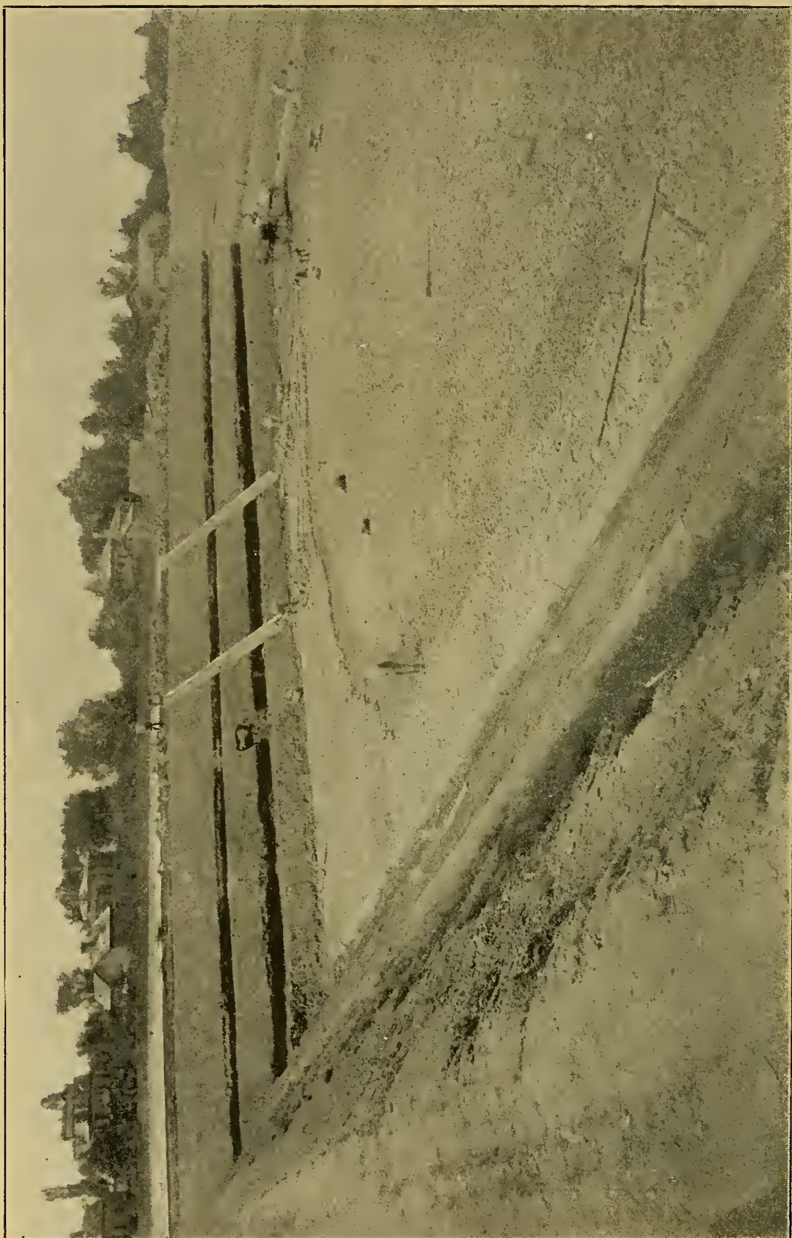
The Burlington water works comprise about thirty-five miles of street mains, about twenty-two miles of which are cast iron; two earth work low service reservoirs, with a combined capacity of about seven million gallons; one iron high service reservoir with a capacity of 163,000 gallons; a motor to furnish the supply for the high service; two Worthington pumps which formed a part of the original installation; two forty horse power horizontal tubular boilers and a twenty-four inch cast iron intake conduit nearly three miles in length, which was laid in 1894.

The new reservoir holding about four million gallons, was built in 1888, having a concrete bottom and slopes lined with brick laid in cement except for the upper third, against which the fluctuation of ice in winter is expected, which is lined with granite laid in gravel. The cost was about $23,000. Two years later about $11,000 were expended in remodeling the old reservoir, bringing it to the same general plan as the new one. Since then it has become possible to thoroughly clean the reservoirs, and that work has been done regularly each season, and there has been hardly any cause for complaint on account of fishy taste and odor.

The high service supply is furnished by a motor, designed and built by Mr. W. H. Lang of this city, which, for every 20 gallons passing through it either to or from the lower reservoir, forces about a gallon to the higher level. The motor is situated in the low service main in the low service reservoir yard and pumps directly into the distribution pipes of the high service, the surplus going to the high service tank, and in case the later overflows, the excess returns to the lower reservoirs.

The iron high service tank is thirty feet in diameter by thirty-two feet in height and rests on a stone foundation built up from solid

PUMPING STATION.



RESERVOIR DURING CONSTRUCTION.

ledge and is enclosed in a brick building with slated roof. The eight inch combined inlet and outlet pipe enters the tank about a foot above the bottom. A four inch overflow from the top conducts surplus back to the lower reservoirs. On the bottom a four inch blow-off is attached. On the side of the tank about two feet above the bottom and directly opposite the door of the brick building is an eliptical man-hole of sufficient size to admit men and tools for cleaning. Both the outside and inside of the tank have been covered at different times with several different paints and coatings, of which Alkatraz asphalt seems to give the best satisfaction.

Meters were used in Burlington even before the works were purchased by the city and since then the number has been constantly increasing. On the high service, a meter is required on every service where there is a sewer connection, owing to the insufficiency of the supply, the motor having for some time past been greatly over taxed. Meters are also required on all services larger than half inch used for other than fire purposes. Half inch meters are furnished by the city free of charge, the taker being at the expense of setting the meter in a manner approved by the department. Meter testing is conducted in the water works store room, which is conveniently fitted for that purpose and is abundantly supplied with water from a four inch service.

Our average daily consumption has now reached a point slightly in excess of the capacity of one pump, running all the time, and a new pumping plant will probably be soon installed both to secure greater capacity and the greater economy in operation of modern pumps over those of a quarter of a century ago.

From the construction of the works in 1867-8 to the fall of 1894, Burlington drew her water supply from a short distance from the face of the dock at the north of the bay and emptied her sewage at the south of the bay, of late years into a nicely, though entirely unwittingly, prepared settling basin. During all these years the sewage output has been on the increase but the various committees who have been delegated to investigate the matter have reported that though it was possible for the city's water supply to become contaminated from its proximity to the sewer outfall three-quarters of a mile distant, it was not at all probable. Later the above mentioned settling basin became a nuisance and the city forced to abandon it and proposing to empty her sewage directly into the bay

off the face of a dock, it became apparent that the condition of the intake all ready none too good, was likely to become worse.

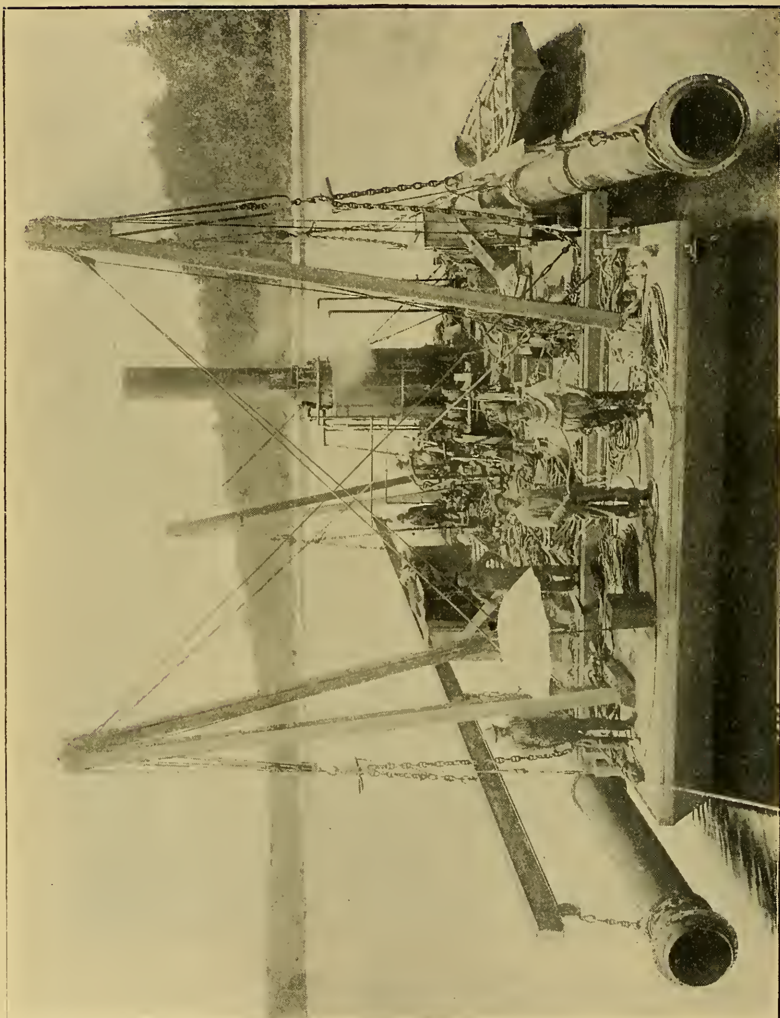
Steps were immediately taken to remedy the evil and after a careful investigation of the possible sources of gravity supply and the different locations at which water could be taken from the lake, it was decided to locate the intake on what is known as Appletree Reef, just outside of the bay next north of that on which the city of Burlington is situated. Plans and specifications were prepared for the extension, the work was advertised and on October 7th, 1893, eight bids, ranging from $56,919 to $145,000 were opened at the water office. As the lowest bid was considered too high, bids were again asked for and just one month later, five were received, ranging from $47,900 to $59,500 and the contract was awarded to Mr. J. G. Falcon of Evanston, Illinois, the lowest bidder.

The intake conduit is of coated cast iron pipe, 24 inches in diameter, and was laid in sections of seventy-five feet each, connected under water by means of Falcon ball joints. This joint is made of a ball cast of such diameter, larger than the pipe on which it is to be used, as to admit the desired deflection to be obtained without obstructing the water way, and a flanged spherical ring of about three-eighths inch greater radius than the ball and of such width that the ball cannot pass through it. These two parts are leaded together and attached to one end and a flanged bell, planed so as to make a tight thimble for the ring which is attached to the other end of a section to be laid.

The flanged joint is made by a diver with the aid of a thin rubber packing, and after it has been for a short time in our lake water the oxidation which takes place on the planed surface of the ring and thimble makes it entirely water tight. In a case like that of our intake, where there is no current of constant and high velocity to keep open and increase the size of leaks induced by changes of temperature or settlement, it may safely be expected that all small holes will be closed by oxidation. The 75 foot lengths of regular bell and spigot pipe were leaded together on shore in the usual manner and were tested by hydraulic pressure, a special flange being bolted to each end for that purpose.

The scow used for laying the pipe was built and work commenced at the station in the winter and before the opening of navigation. The pump well was sunk, pipe laid through it from the face of the

FASTENING FLEXIBLE JOINT.



ON SCOW.

dock and a 24 inch gate placed on the conduit in the well. By closing this gate and placing a flange on the outer end of the last section laid, it became possible at any time to test the conduit in place in the same manner in which the sections had previously been tested on shore.

The outer or intake end of the conduit is located in about 30 feet of water on Appletree Reef, the end being turned up at an angle of ninety degrees and the size of the conduit increased at the bend to 30 inches. The highest point of the copper screen, which caps the upright, stands about fourteen feet below the surface at ordinary low water, and about five feet above the oak crib filled with stone which surrounds the upright. By closing a 24 inch gate, located just outside of the crib and the one before mentioned in the well at the pumping station, and forcing water under pressure into the conduit between the two gates, the tightness may at any time be easily tested. The tests which have been made, since the completion and acceptance of the work, have in each case proved satisfactory.

DISCUSSION.

Mr. Noyes. If I understood him correctly, Mr. Crandall said that in the early part of the work, iron pipe was used, and that it did not give satisfactory results as compared with cement pipe. I would like to ask if there was any special reason to account for that, whether it was a poor iron, or whether it was owing to the peculiar quality of the water which acted upon the pipes?

Mr. Crandall. I think that the trouble was occasioned by the quality of our water, which very readily attacks iron, and by the fact that there was no coating on the pipe. There was quite a lot of four inch pipe used by the Aqueduct Company, which was taken up at the time the new works were put in, and the pipes fell to pieces in taking them out of the ditch. Several years later, since my connection with the works, we amused ourselves when taking up some four inch pipe by stamping upon it and breaking it in. It was soft from end to end, and the iron thoroughly oxidized. We have a six inch main on Pearl street, uncoated pipe laid prior to 1865, which we expect will flood us every time we tap it.

Mr. Noyes. I would like also to ask Mr. Crandall if he is now using coated iron pipe on the extension of his works, and if the water appears to attack the iron in the same way that it did the uncoated pipe?

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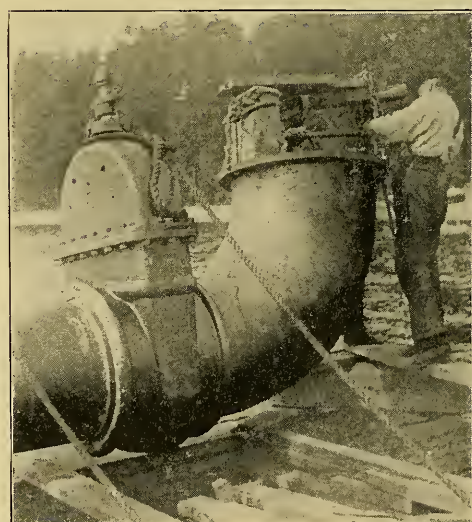

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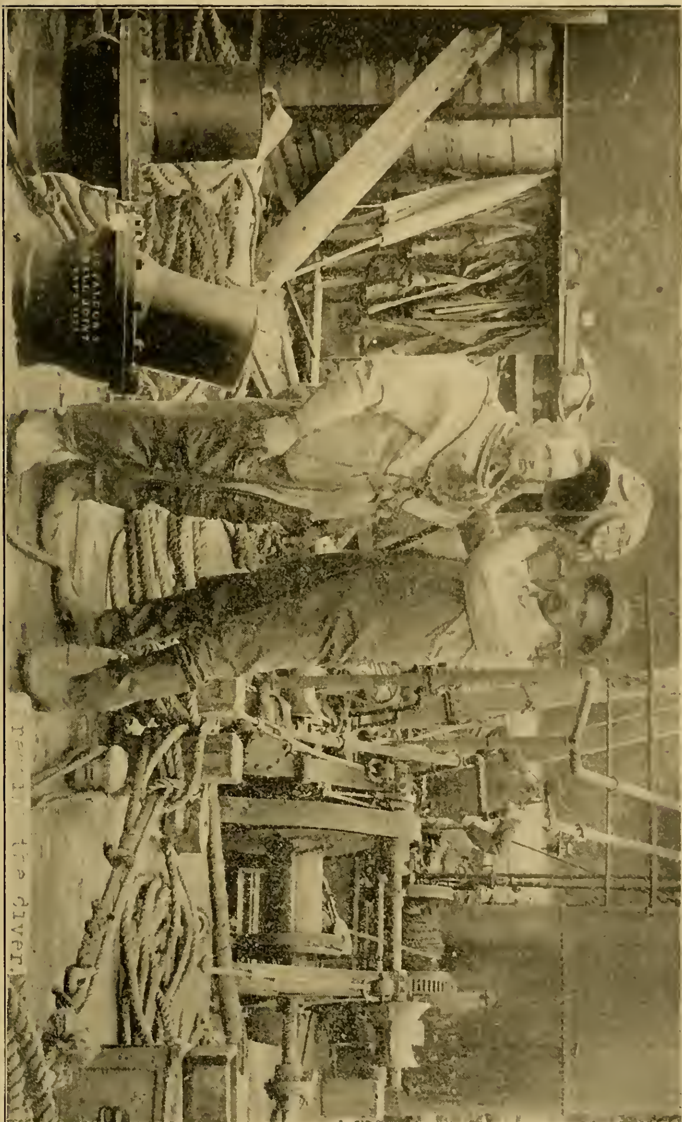
1—Screen. 2—Crib. 3—Gate and Bend.



PREPARING TO DESCEND.

Mr. Crandall. We now use ordinary cast iron coated pipe. In 1888, we took out some pipe which had been down for 25 years, and it was found to have hardly a speck of rust on it. We are constantly taking out pieces of coated iron pipe which are in good condition.

A Member. I would like to ask about the material used for coating the high service tank, particularly the inside.

Mr. Crandall. We have used the government water-proof paint; the Dixon Graphite Company furnished us with a sample, and a local paint dealer has tried his hand at it; in fact the paints which have been used on that tank are too numerous to mention. About four years ago the Alkatraz Asphalt Company of Portland, Oregon, offered to give us a barrel if we would pay the freight on it, and the asphalt is now on the tank inside and out, covering about a quarter of the surface, and thus far it has proved satisfactory. It does not peel and the ice does not seem to affect it; it is just as good where the fluctuation occurs as it is at the bottom.

Mr. Williams. I would like to enquire a little more about the test of the intake. Mr. Crandall stated that the tests were satisfactory; but I would like to know exactly what his tests were, and their results.

Mr. Crandall. The pipe is laid on a bottom which is nearly level, but there are two summits in the distance, and on those summits were placed brass ferrules with two one-eighth inch holes bored in each ferrule. Before these holes were opened, the water was let on at a pressure of about 20 pounds, and we noted the amount of leakage and the same was done afterwards, showing the leakage occasioned by the holes. This was done each time that air vents were placed, and when the test was finally made, the pressure which they were subjected to was from 12 to 15 pounds, and the leakage, aside from that through the air vents, was about 100 gallons per hour in the entire length of about three miles.

Mr. Gilbert. I would like to ask a question in regard to the action of water on iron. We have all noticed that some pipe will fill up with rust much quicker than other pipe, not only in the mains, but more particularly in services. I am speaking of plain iron pipe, not coated pipe. Now it seems to me that this difference must be due to the quality of the iron; and I would like to know what quality of iron is least acted upon.

A Member. I find that all common iron pipe, standing in water, will rust at about the same rate, and as far as I can see, the quality of the iron makes no difference. I think the filling up of a common iron pipe depends largely upon the pressure; services where the pressure is low fill up quicker than where it is higher. I have also noticed that the rust upon common iron pipe is much more easily washed off than it is from a coated pipe.

Mr. Gilbert. We had a case where two services were connected with a main within two feet of each other. They were both laid the same year, but probably not from the same lot of pipe. The water from one of those services was satisfactory all the time, but from the other it was hardly fit to use. The water from all the other services along the street was good. The service pipe was finally changed and there has been no further trouble.

Mr. Fish. I have always found that rapid rusting of service pipes has been accompanied by leaks, so that the water is constantly flowing through the pipes, and I would suggest that leaks be looked for in all such cases.

Mr. Hazen. One of the most interesting features of this Burlington supply is the use of Lake Champlain, both as a source of water supply and as a receptacle for the sewage of the city. That is a case which does not occur very often in New England, but which is much more common in the West. On the shores of the Great Lakes there are a number of cities, many of them much larger than Burlington, that are doing this same thing, and the question comes up in all these cases, how much is it necessary to dilute the sewage in order to make it safe for drinking water; or, in other words, how far out must the water intake be placed in order to get a safe or healthy drinking water, or can the intake be so placed at any reasonable distance as to give a safe water?

There are cases, as for example those of Chicago, Cleveland, Toronto and other lake cities, where the water has been taken from points too near the sewer outlets, and there has been so much sewage in the water that the cities have suffered from very high death rates and from sickness which they ought not to have had, and would not have had with better water; but, on the other hand, we must admit that there is a distance from which water may be taken that is far enough away from the sewer outlets so that the sewage will have at least no very great effect upon the health of the city.

The Chicago sewage mixes with the water of the lake and pollutes it so that, as I believe, it is not suitable for drinking, even at the four mile intake; but following the case further, we find that the sewage mixes with the water of Lake Michigan and eventually goes down through the Mackinaw Straits into and through Lake Huron and finally into the Detroit river and into the drinking water of Detroit. But after it has passed through these two great lakes and has become so enormously diluted and exposed to the air and light for months, no one would claim there was any serious danger from the Chicago sewage to the Detroit water. The engineer of the Detroit water works is here, and I think if he were looking for possible pollutions of the Detroit supply, he would look for them at points much nearer than Chicago. But the intake of the Chicago water works and the intake of the Detroit water works are a long distance apart, and the interesting question is at what point between those two limits does the water become safe for drinking and suitable for public water supply.

It seems to me that there is not any sharp line, but that the further the intakes are carried out the less the danger becomes. When Chicago carried her main intake out from two to four miles and abandoned at the same time the use of the old shore inlet, some three years ago, the death rate from typhoid fever in the city in the next year was reduced by 60 per cent., or to 40 per cent. of what it had been before.* That was regarded as a great achievement, and it was. The water was better, but it was and still is far from what it should be. The city, even since the reduction, has an enormously high death rate when it is compared with other cities with good water supplies. The four miles was not far enough; and it will be necessary to go much farther than that in order to secure a good water. Of course the distance to which it is necessary to go, depends in different cases upon the amount of sewage which is put in, and a large city like Chicago, disposing of the sewage from over a million people, pollutes the water to a greater extent and for a greater distance than a smaller place would do.

The question is naturally raised as to how much disease a water must cause in order to make it worth while to incur a heavy expen-

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*The Water Supply of Chicago, its Source and Sanitary Aspects, by Arthur R. Reynolds, M. E. Commissioner of Health of Chicago, and Allen Hazen, American Public Health Association, 1893. Page 146.

diture to prevent it. It seems to me we have got to put this question upon something the same basis that we do the cases of other works for saving human life. If it is a question of abolishing a grade crossing, a city will not incur an expenditure of millions of dollars to save one or two human lives, but if the expenditure is less, or if many lives can be saved, the improvement will be demanded. It is necessary to show that the value of the lives bears some relation to the expense which is to be incurred in making the change. And that is what I believe should be done in regard to works for improving the quality of water supplies. The method which has suggested itself to me is to take the deaths which can be attributed with some degree of certainty to the water, and the losses arising from the sickness which comes from the same source, and estimate their value upon something the same principles which are used in other cases where the damage to and loss of human life are involved, including also an allowance for indirect damages, such as depreciation of property, etc., which cannot be so accurately estimated, and balance the damages done by the water, calculated in this way, against the cost of the works which would be necessary to secure a water which would avoid them, or most of them, and then determine whether the saving is enough to justify the expenditure of the money necessary to make the changes.

And I think you will be surprised in many cases, to find how great the saving will be, and how much expenditure it will justify to avoid the sickness and death. Take for example Chicago. In 1891, 1997 deaths were reported from typhoid fever. Probably more than 15,000 other people were seriously sick from this disease but did not die from it. The fever was, in my opinion, mainly due to the use of the Chicago water. It may be said that some cases would have occured had the city had ever so good a water supply, but on the other hand there were hundreds or thousands of other cases which were contracted in Chicago by people who were there temporarily, or who were working there, and left the city after they had contracted the disease, and so a part of typhoid fever contracted in Chicago was charged to the account of the cities and towns to which these people went. Taking this into account, I do not think the figure given is an over-estimate of what was actually caused by the water. Most of the victims were people in the prime of life; there were few children and few old people. All classes of

society were effected to substantially the same extent, for we found that the wards along the lake front, where the finest residences in Chicago were located, had just as high death rates as those on the west side, and those along the Chicago river, which were in bad sanitary condition, and were commonly supposed to be the main strongholds of the disease.

Taking these facts into account, it seems that a value of not less than $5,000 should be put upon each of these lives, and that, for 2,000 lives lost, you see, aggregates $10,000,000 loss in one year alone, and that without taking into account the enormous number of cases of sickness which did not result fatally, or the diarrhœa and other minor injuries to health which were undoubtedly caused by the water, but which do not appear in the statistical reports of the Health Department. That $10,000,000 was the loss in one year, and was followed of course by other sums for other years, and the loss is of such a magnitude that it would fully justify very heavy expenditures to prevent it, such as would allow the positions of the intakes to be radically changed, or the treatment of the sewage, or the filtration of the water, as it has been found at Lawrence and in Europe it can be done, so as to render it safe for use. The case of Chicago is not exceptional, as precisely the same conditions prevail to a greater or less extent in many other cities. It seems to me we have got to look at this question in this general way, balancing the losses which result from the use of a poorer water, as nearly as we can calculate them, with the cost of improving the supply.

Professor Sedgwick is going to tell us tonight something about the conditions here in Burlington. I believe that they are comparatively good, and that Burlington, being a small city, and having extended the water intake out, as Mr. Crandall has told us, some three miles, the water obtained is comparatively good and the city has a low death rate from typhoid fever. But there are plenty of other cases where the conditions are different, and where the death rates are high, and it is a question which must be carefully examined wherever it is proposed to put sewage into the same body of water from which drinking water is taken.

ON THE SANITARY CONDITION PAST AND PRESENT OF THE WATER SUPPLY OF BURLINGTON, VERMONT.

BY

WILLIAM T. SEDGWICK,

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To the student of hygiene the sanitary history of the water supply of Burlington, Vermont, is peculiarly interesting and instructive. Burlington is the only city in New England which derives its water supply from the same lake into which it empties its sewage, although this arrangement for water supply and sewage disposal is common enough in other parts of the United States. It also affords a notable example of a community which has long used a suspected water without having suffered excessively from typhoid fever while yet exhibiting a condition of widespread and continued diarrhœal disturbance among its inhabitants; a condition which was apparently entirely due to consumption of impure water and has been apparently entirely corrected by simply increasing the distance between the sewer outfall and the water intake in the lake.

The location of Burlington is all that could be desired. Situated at the eastern extremity of Burlington Bay, on Lake Champlain, it occupies a very favorable sanitary position. The city is closely built over a small area only. For the most part it has an open suburban character and rests upon, or at the foot of, a hillside which rises rather abruptly from the lake and leads to an elevated and very extensive terrace or table-land stretching many miles to north and south, as well as eastward to the nearest hills—the higher ranges of the Green Mountains—some twelve miles away. Built thus upon the rather sharp declivity by which this broad terrace passes into the lake; with the Green Mountains on the east, and on the western horizon the sinuous line of the Adirondack peaks; while at its feet

the long lake reflects the shafts of sunlight and tempers the hot breaths of summer, the city has naturally a most fortunate situation. The climate, though cold in winter, is salubrious and the natural drainage excellent.*

Water in superabundance is at hand; and when, in 1866, the citizens determined to have an ample public water supply for fire and other purposes they naturally turned first of all for a source to Lake Champlain. Yet they did not finally decide to use the lake without due deliberation and careful inquiry.

"In 1866, when the matter of building our water works was under discussion, a gravity supply from Brown's River, in Jericho, was alluded to, and the matter was disposed of in the report in the following words: 'At no distance less than about eleven miles can we obtain a supply of water by gravitation from any place, and as this would involve an expense of about $500,000 such a mode of obtaining water at this time is out of the question.'"—(*Annual Report of the Water Commissioners of Burlington, Vt.*, for 1889, p. 95.) It was accordingly decided to abandon the idea of a gravity supply and to pump from the lake into the pipes, the surplus going to a reservoir at the top of the hill.

The water works were built in 1867, the intake being located on the lake front near the northern extremity of the docks. They appear to have given at first entire satisfaction. "At no time has the city water supply held so high a place in the public estimation."—(*Sixth Annual Report of the City of Burlington*, for 1870, p. 122.) As early as 1871, however, attention was drawn by the Health Officer (Dr. H. A. Crandall,) to the desirability of extending the intake further into the lake. "The prospect of increased sewerage, the increased shipping about the docks, the great amount of surface water flowing into the lake from our streets, besides other important reasons, influence me to recommend an extension of the pumping main at the

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*"Nature has done much to render Burlington both beautiful and healthful. It is unsurpassed among the places noted for the beauty of their location and their natural surroundings. Situated in the midst of mountain scenery, and bounded on the west by Lake Champlain, it possesses everything to contribute to good health. Opportunities for health-giving exercise abound, in walks, drives, mountain-climbing and yachting. * * * *

"The climate is not excelled for salubrity. While the vicinity of the lake modifies the extremes of temperature, both in winter and summer, the atmosphere is unusually bright and clear, and the proportion of sunshiny to cloudy days is about five to one in all seasons of the year."—(*Annual Report of the Health Officer—Dr. H. A. Crandall—for 1893.*)

pump house of the water works farther into the lake, say 300 feet or more, to deep and *pure* water."—(*Seventh Annual Report*, for 1871, p. 85.)

The occurrence of 5 deaths from dysentery and 3 from diarrhœa in 1870, and of 10 from dysentery in 1871, suggest that the "other important reasons" referred to by Dr. Crandall may have been the prevalence of diarrhœal disturbances. However this may be, the Health Officer for 1874 (Dr. A. P. Grinnell,) appears to refer to such a condition in his annual report for that year, and to have been moved to make an investigation. "It is generally believed that the water obtained from the lake is chemically pure and wholesome; but the prevalence of a certain class of disease whose origin could be traced to impure water or food has led me to make a more thorough investigation of the matter, and now I am able to place before the Board [the city council] the results of experiments, and the conclusions at which I have arrived, respecting the impurity of the water supplied to the people of this city."—(*Tenth Annual Report*, for 1874, p. 76.) The Health Officer then gives the results of chemical analysis of the water of the lake at the intake, one specimen having been collected from the surface and one from near the bottom, and continues: "The amount of organic matter found in either specimen is sufficient to warrant the statement that the water now supplied to the city contains impurities which are capable of generating diseases of a grave character. * * * * We can safely presume that the water consumed by the city is much of the time unfit for use. * * * * The necessity of supplying pure and wholesome water for purposes of drink and diet is apparent to everyone; but it is hardly possible to obtain such supplies from a point in the lake only *sixty feet* from the docks—the natural reservoirs for the excrementitious matter found in sewage." Dr. Grinnell also advised the extension of the intake pipe, "to or beyond the breakwater." (*loc. cit.*) This advice was repeated in the next Annual Report by the Health Officer for 1875 (Dr. C. P. Thayer.)

On the other hand, in the *Fourteenth Annual Report*, for 1878, p. 198, the Health Officer (Dr. H. H. Atwater) states: "In my observation of the diseases of this city and their causes during the period from the introduction of the public water supply to the present time, I have been unable to trace any distinct ill effects from the present source of supply. Typhoid fever, the disease which, of all others, we should

expect to result from sewage contamination of drinking water, is of infrequent occurrence in this community. There has been only one death from this disease during the last year, and this of a man over 70 years of age. Diarrhœa and dysentery occur here sporadically, and are not virulent, and prevail mostly during the summer months, so that they may be more reasonably attributable to the debilitating effects of heat, over-exertion and other causes, than to impure drinking water. * * * * Still, it seems to me that as the number of public sewers and the amount of sewage flowing directly into the lake yearly increases, it would be wise for the city to consider soon the propriety of obtaining the water at a greater distance from the shore."

In 1882, out of a total of 254, there were eight deaths from typhoid fever and eight from diarrhœa and dysentery, besides three from cholera morbus—a sum of diarrhœal disease which amounted to an epidemic.

In 1883 the Health Officer (Dr. John B. Wheeler) states: "First in the list of improvements, by which the public health would unquestionably be benefited, is the extension of the water main to some point outside the breakwater. * * * * It can hardly be doubted that much of the diarrhœal trouble so common in Burlington is due to the condition of the city's water supply. To extend the water main beyond the breakwater would be to take it beyond the reach of contamination and give our citizens a supply of pure water."—(*Nineteenth Annual Report*, for 1883, p. 88.)

Dr. Wheeler, as Health Officer, in the next annual report, says: "Some alarm was created, in the early summer, by the appearance of typhoid fever in the city. The alarm was owing not so much to the number of cases, which was not large, as to the existence of the disease, which is almost unknown in Burlington, except when an occasional case is imported. The number of fatal cases in 1884 was 10. * * * * The character of our water supply has been the subject of a good deal of discussion during the past year."—(*Twentieth Annual Report*, for 1884, pp. 55, 56.)

In 1885, the Mayor of Burlington, in his annual *Message*, said: "The subject of a supply of purer water for our city has been much discussed, and opinions are various among our citizens. * * * * Several analyses of water taken from different parts of the lake,—and from other waters than the lake,—have been made by compe-

tent chemists, and they indicate that we should not be materially benefited by changing the present source of supply. Whether analyses should be taken as conclusive evidence of fitness or unfitness of water for human use I am not prepared to say, but common sense would teach that, other conditions being equal, the greater the distance water is taken from a source of infection, the purer it will be." In the same report (*Twenty-first Annual Report*, for 1885) the Health Officer, Dr. J. H. Linsley, remarks: "The fact that no case of typhoid fever was reported to the Health Officer during the year refutes the possibility of the cause of the appearance of this disease in 1884, being in our water supply, as was at that time suggested."

During 1884 and 1885 numerous chemical analyses were made and in the Mayor's message, delivered on April 5, 1886, we find the following conclusion based upon them: "Some two years since the water committee were directed to examine into the subject of our water supply, and to report the result of their investigations to the board. They have just made their report, which contains the results of many analyses of water taken from various localities in the lake. The report imparts the gratifying assurance that the water at the point from which it is now pumped is as pure, if not purer, than at any other locality in the lake. There are some people who do not appreciate the value of the findings of the committee."—(*Twenty-second Annual Report*, for 1886, p. 13.) In the same *Report* (p. 74) the Health Officer (Dr. J. H. Linsley) remarks: "More or less discussion is constantly going on in regard to our present water supply, and many views are entertained as regards the comparative purity of the water used. I am unaware that the existence of any disease was ever traced to its impurity. But I think no one will deny that the surroundings of the suction-pipe, as at present situated, are not such as would tend to quiet the misgivings of anyone who is inclined to be skeptical in regard to the purity of the water at our present source of supply. I would respectfully recommend that when it is seen fit to extend the suction-pipe into the lake, such extension be made far enough to be beyond the *possible* contamination of the sewage from this city. Of course, the construction of the sewer in Battery street removes nearly all the sewage that formerly emptied into the lake at the foot of College street, to a point fully half a mile further south." Also, in the

same *Report* (p. 99), the superintendent of water works (Mr. F. H. Parker) states: "By a vote of the board of aldermen, May 17th, 1886, the city treasurer was authorized to borrow $24,000 * * * * for the purpose of * * * * and extending the suction-pipe to the pumps farther into the lake." * * * * "A city meeting was called, * * * * but the resolution authorizing the work was dismissed, and the improvements have not been carried out."

For 1888 we find in the report of the Health Officer (Dr. J. C. Rutherford) the following: "There was more sickness during the year just ended than for several years past. * * * * Different types of fever prevailed during the late summer and autumn, some of them taking a typhoidal form. The mortality from them, however, was very low. On December 24 I sent to the physicians of the city a circular letter requesting them to give me, to the best of their knowledge, the number of cases of fever they had attended during the past year. Nearly all replied, and although they said they had no record of their cases, the number they remembered was, in the aggregate, very large. They ascribed the cause of so much sickness to, First—the long-continued wet weather. Second—the sudden changes of temperature; and Third—the unwholesome condition of the aqueduct water. * * * *

"There have been reported to me twenty-six cases of typhoid fever. The source of only two could be traced from out of town; the rest, beyond any reasonable doubt, originated here. Many other cases were reported as typhoid, which, upon examination, I found to be of another type of fever. * * * *

"The water supply of the city has again become a prominent topic of conversation. Owing to the great amount of sickness during the summer and autumn, people have begun to question the purity of the aqueduct water."—(*Twenty-fourth Annual Report*, for 1888, pp. 74–77.) In the same document Mr. F. H. Crandall, who began his service as superintendent on April 25, 1888, (succeeding Mr. Parker, who became chairman of the newly-established water commission), in making his first report, says (p. 131): "The unusual amount of sickness in our city for some time past has again called public attention to the purity of our water supply. Various plans for its improvement have, for some time past, been under consideration, * * * * and investigations are now in progress as to the relative merits of different sources of supply."

The results of the "investigations" here referred to appeared in the next Report (*Twenty-fifth Annual Report of the City of Burlington, Vt.*, for 1889, pp. 95, 105, 113. See also *Twenty-third Annual Report of the Water Department, City of Burlington, Vt.*), and consisted mainly of a report of progress. The documents referred to are duplicates, and include statements from the commissioners and superintendent, and a lengthy and interesting summary of the situation from the chemical standpoint by Mr. Joseph L. Hills, chemist of the State Agricultural Experiment Station of Vermont. From Mr. Hills's report is taken the table of analyses given on the next page.

Mr. Hills himself added to this list twenty-three more chemical analyses, made at the Experiment Station between May and November, 1889, from the city service, various points in Lake Champlain, and several places from which it had been proposed to obtain a gravity supply.

From his several investigations Mr. Hills concluded that "The testimony of chemical analysis would appear to be, so far as one year's experience can indicate, that all the [proposed] sources of supply are of medium purity, except perhaps, Hinesburg Pond. * * * * The station chemists have not been able to detect evidences of sewage in samples from Mark's Bay or the pumping station (or indeed in a series of samples taken about one hundred yards away from the sewer mouth in the endeavor to trace the direction of sewage currents.) * * * * One of the most interesting points * * * * is that the water from the broad lake does not appear purer than that taken inshore. * * * * It does not appear settled that the extension of the suction-pipe will of necessity give our community a purer water supply."

Reviewing all the facts and data observed or collected up to this time, the superintendent (Mr. Crandall) wisely and truthfully remarked in his annual report for 1889, that they "afford a subject for careful thought and study, as well as a chance for interesting comparisons."

In 1890 the Health Officer (Dr. J. C. Rutherford) reported that "During the present winter there has been in the city a mild epidemic of diarrhœa, which some people supposed was caused by impure water. A meeting of the State Board of Health was called in this city, at which several of the prominent physicians gave their

Chemical Analyses of the Water Supply, Etc., of Burlington, Vermont, Previous to May, 1889.
[Compiled by Joseph L. Hills.] [Parts Per Million.]

Source of Sample.	Date.	Analysis By	Free Am.	Alb. Am.	Total Solids.	Fixed Solids.	Vol'tle Solids.	Chlorine.
Hydrant	1882	Mallet	0.035	0.14	70	20	50	0.7
Service Supply, Elmwood Avenue	Sept., 1884	Sabin	0.04	0.18	164	.....	.....	.....
Mouth of Suction Pipe, Pumping Station	"	Sabin	0.16	0.16	36	.....	.....	.....
" " " " "	"	Witthaus	0.052	0.13	72	.....	.....	2.1
" " " " "	March, 1885	Witthaus	0.034	0.10	89	.....	.....	1.1
" " " " "	"	W. R. Nichols	0.02	0.15	71	57	14	0.2
" " " " "	"	Seeley	.....	.....	60	41	19	.....
" " " " "	Jan. 8, 1889	Hills	0.03	0.18	88.5	54.5	34	1.7
Northwest corner of Breakwater, 10 feet deep	Sept., 1884	Sabin	0.06	0.114	119	.....	.....	.....
" " " " "	"	Witthaus	0.026	0.11	84	.....	.....	1.5
" " " " "	March, 1885	Witthaus	0.016	0.08	75	.....	.....	1.1
" " " " "	"	W. R. Nichols	trace	0.08	73	60	13	2.0
Foot of Bank Street	Jan. 8, 1889	Hills	0.02	0.19	86	49	37	1.4
Northwest corner of Breakwater, 26 feet deep	Sept., 1884	Witthaus	0.146	0.17	79	.....	.....	1.8
" " " " "	March, 1885	Witthaus	0.034	0.08	76	.....	.....	1.0
" " " " "	"	W. R. Nichols	trace	0.08	70	55	15	1.8
Marks' Bay, 58 feet deep	Sept., 1884	Sabin	0.048	0.10	107	.....	.....	.....
" " 62 " "	"	Witthaus	0.08	0.10	56	.....	.....	5.8
" "	March, 1885	Witthaus	0.034	0.05	66	.....	.....	0.9
" "	Jan. 8, 1889	Hills	0.03	0.16	80	45	35	2.9
Surface, midway Sewer mouth to South end Breakwater	Sept., 1884	Sabin	0.04	0 072	100	.....	.....	.....
" " " " " " "	"	Witthaus	0.08	0.13	116	.....	.....	9.7
Three thousand feet west of Pumping Station	March, 1885	Seeley	.....	.....	69	52	17	.....
Rock Point	"	Seeley	.....		61	44	17	.....
Reservoir Water, 48 hours pumped	Sept., 1884	Sabin	0 093	0.168	129	.....	.....	.....
Reservoir Water, (*Old Reservoir*)	Dec. 29, 1888	Hills	0.03	0.16	80	45	35	2.9
Reservoir Water, (*New Reservoir*)	"	Hills	0.03	0.18	88.5	54.5	34	4.3
" " "	Feb. 12, 1889	Hills	0.04	0.14	.....	.....	.....	2.4
Hinesburg Pond	March, 1885	W. R. Nichols	0.06	0.20	63	50	13	2.6
" "	"	Seeley	.....	.....	53	33	20	.....
" "	Feb. 13, 1889	Hills	0.04	0.15	93	43	50	3.7

testimony, and the majority of them were of the opinion that the sickness was caused more by the variable weather than by the water. Anyone who doubts the purity of our water would be convinced that it is pure if he will take the trouble to visit the pumping station and the reservoirs." (*Twenty-sixth Annual Report* for 1890. p. 73.)

In spite of this "mild epidemic of diarrhœa," no death from this cause is reported for either 1890 or 1891. Two deaths were reported in 1890 from dysentery, one each from typhoid and continued, and two from typho-malarial fever.

The total mortality, the typhoid fever mortality, and the percentage which the latter was of the former, for the twenty-six years 1870–1895, are shown in the following table:

TYPHOID FEVER* MORTALITY IN BURLINGTON, VT.

(1870–1895.)

Year.	Total Mortality.	Typhoid Fever Mortality.	Mortality Percentage from Typhoid Fever.
1870	169	2	1.18
1871	146	6	4.10
1872	157	2	1.27
1873	228	..	....
1874	152	..	....
1875	145	..	....
1876	148	2	1.35
1877	202	4	1.98
1878	183	1	0.54
1879	228	2	0.87
1880	219	3	1.37
1881	226	2	0.88
1882	254	8	3.15
1883	242	1	0.41
1884	238	10	4.20
1885	266	1	0.37
1886	262	4	1.53
1887	286	4	1.05
1888	375	9	2.40
1889	248	8	3.14
1890	300	4	1.33
1891	272	4	1.47
1892	336	6	1.77
1893	306	10	3.26
1894	311	2	0.64
1895	311	1	0.32

*Including "typhoid," "continued," "slow," "enteric," "bilious," and "typho-malarial" fevers.

Mortality from Typhoid Fever per 10,000 Inhabitants in Census Years.

Year.	Population.	Deaths from Typhoid Fever.	Deaths from Typhoid Fever per 10,000 Inhabitants.
1870	14,387	2	1.3
1880	11,364	3	2.6
1890	14,590	4	2.7

The general situation when, in 1892, I was invited to make an investigation of the sanitary condition of the water supply appears, from what has thus far been brought together, to have been somewhat as follows:

First. It was widely held by physicians, and understood by the people, that diarrhœa was common among users of the water, especially those who had not become habituated to it, visitors to Burlington, if they drank the water, frequently suffering from some diarrhœal disturbance.

Second. The location of the intake of the water works was less than a mile from the outfall of the main sewer, and only a few rods from the docks.

Third. Typhoid fever, the ordinary measure of the sanitary condition of a water supply, was not then, and had seldom been, excessively prevalent in Burlington.

Fourth. Chemical analyses had indicated that the water supply of Burlington was at least the equal in purity of many well-known and excellent water supplies.

Fifth. Chemical analyses had failed to show any marked superiority in the water of the broad lake (the middle of Lake Champlain) to that at the intake, on the shore of Burlington Bay.

Sixth. Investigations had proved that it would be difficult, uncertain and costly, to procure a gravity supply from the mountains, because of their remoteness and for other reasons.

It is only fair to add that at the time of my own investigations and of making my report I was less familiar with some of these facts than I am now.

Previous to 1892 the sewer outfall had frequently attracted the attention of physicians and other citizens. When the water in the lake was low the sewage from the main sewer was not discharged

into the lake beneath the surface or even on the lake front, but ran in an open stream over flats laid bare by the receding waters of the lake and emptied into a small bay or basin connecting with the lake. The stench which at times arose from this torpid stream, from the flats and the bay, were highly obnoxious and objectionable, so that a demand had come, especially from the Board of Health and its efficient Health Officer, Dr. H. A. Crandall, for an improved outfall. Mr. F. P. Stearns, C. E., Engineer-in-Chief of the State Board of Health of Massachusetts was finally consulted, and advised an extension of the outfall to the main lake front with disposal there directly into the lake, and at a depth sufficient to be always below the surface.

I had already been making (in Boston) occasional bacterial analyses of the city water, the water of the lake, etc., for the water commissioners of Burlington, when, on June 20th, 1892, I was invited by them to visit the city and make a thorough investigation of the sanitary condition of its public water supply, present and prospective. I did as I was desired and subsequently presented a Report, of which the following is the principal portion:—

BOSTON, JUNE 30, 1892.

"*To the Board of Water Commissioners, Burlington, Vt.*

"GENTLEMEN:—I have the honor to submit to you a report upon my investigations, made at your request, concerning the sanitary condition of the Burlington water supply and the probable sanitary effect of certain proposed changes therein.

"I am informed that many of the physicians regard the water supply with suspicion, and I find that the successive Health Officers in their official reports have frequently referred to the water as more or less objectionable. I therefore undertook, first, to discover the actual effects of the water supply upon the health of the city.

"In order to do this in the case of a water supply suspected of sewage contamination it is customary to take as a measure the prevalence of diarrhœal diseases, and especially typhoid fever. I have therefore carefully studied the vital statistics of Burlington for the last twelve (12) years, comparing the mortality from typhoid fever with the total mortality and also with the number of inhabitants.

"The results show conclusively that the mortality from typhoid fever (and the same is true for diarrhœa and dysentery) has not been large in Burlington during the last twelve years. The average annual mortality from typhoid fever, from 1870 to 1891 in Burlington was 3.57 per 10,000 inhabitants."

I then went on to show that Burlington compared favorably in this respect with many cities having water supplies of undoubted purity, and stated that in respect to mortality from typhoid fever it had a better record than "many cities having water supplies of good reputation. This weighty fact alone justifies the conclusion that there is no positive evidence in the sanitary statistics of the city that the water supply is injurious to the public health. I may add by way of confirmation that during the last three years I have made repeatedly bacteriological analysis of the Burlington supply, and that I have found no satisfactory evidence of the presence of sewage in the drinking water.

"It is interesting and instructive to compare the history of typhoid fever in Burlington during the last six (6) years with that during the earlier half of the period under consideration, for in this way we may learn whether this disease is or is not increasing. If we do this we obtain the following results:—

Typhoid Fever* in Burlington, Vt.

Six-year Periods.	Average Annual Death Rate from Typhoid Fever per 10,000 Inhabitants.	Average Annual Mortality Percentage from Typhoid Fever.
1880-1885	3.39	1.73
1886-1891	3.75	1.83

"These figures are certainly reassuring, and prove conclusively that there is no immediate reason for excessive anxiety or alarm for the sanitary condition of the water supply.

"It is, however, the opinion of many Burlington physicians, based upon their experience that the water supply is responsible for the occurrence from time to time of diarrhœal disturbances which, while

*Including "enteric," "slow," "continued," and "typho-malarial" fevers.

they very rarely result in death, serve to annoy and alarm the citizens. In the present state of our knowledge it is at present impossible to prove or to disprove this theory. The fact appears to be that such disturbances are common, and it is well known that the main sewer of the city empties into Lake Champlain, the source of the water supply, less than a mile from the intake. Whether there is anything more than coincidence in these facts it is impossible to say. In the present state of sanitary science, however, there can be no doubt whatever that the location of the intake of the water works, as near as it now is to the main sewer of the city, is highly objectionable if not positively dangerous. I can only regard it as a constant menace to the sanitary welfare of the city. It must be admitted as entirely possible that unpurified sewage driven by winds or carried by currents may be in the future, if it has not been in the past, conveyed more or less directly from the sewer outfall to the water intake.

"I have, therefore, at your request, considered the probable sanitary advantages of a removal of the intake of the water works to a point in the "broad lake" some three miles from its present position, and also those of a complete change from the lake to a mountain supply.

"In regard to the former—the broad-lake supply—I am of the opinion that it would be of very great advantage from a sanitary standpoint, inasmuch as it would so far remove the intake from the sewer outfall as to make it unlikely that raw sewage would ever pass from the latter to the former; while at the same time it would give more time for the purification *en route* of any sewage which might accidently so pass. Unless the city should become very much larger than it now is, the passage of sewage from the sewer outfall to an intake located, for example, on Apple-tree Reef, through the present sewer basin and the quiet waters of the bay, can only be regarded as a remote possibility.

"I may remark in passing that, in my judgment, one reason for the comparative immunity from epidemics of typhoid fever hitherto enjoyed by this city is that the sewage is held in a small bay for a longer or shorter time, according to circumstances, where it can to some extent become freed from the germs of disease.

"If Burlington could draw its water supply by gravity from mountain streams or storage reservoirs and secure abundant water

from an unpolluted watershed the danger of infection of the water supply would be done away. So far as I can judge, however, there are no streams of sufficient size and purity directly available. Storage would be an unavoidable necessity. But storage, while of great sanitary advantage so far as the germs of specific diseases are concerned, is apt to lead to disagreeable consequences in other directions. The water drawn from storage reservoirs is often more or less colored by peat, stumps, leaves, etc., and it not infrequently suffers fermentation with the development of organisms, acquiring thereby disagreeable and sometimes nauseous tastes and odors. If these compel the citizens to abandon its use and lead them to resort to polluted wells or other objectionable sources of supply, the sanitary consequences may be unfortunate. It will be seen, therefore, that while a mountain supply is in many respects highly desirable it is nevertheless true that its adoption in this case would be attended with the possibility of some undesirable consequences. It must be remembered that every new water supply depending upon the storage of surface water is an experiment. It cannot be undertaken without some risk of undesirable results.

"In fine, I am of the opinion that there is no positive evidence of any injurious characteristics in the present supply. But I believe, nevertheless, that in view of the common occurrence of diarrhœal disturbances reported by physicians, and on account of the menace to the public health involved in the present arrangement, some other source of supply should be found. I think that it would be of very great sanitary advantage to remove the intake as far as possible out into the broad lake. A mountain supply in storage reservoirs would afford complete relief from sewage contamination, but might involve serious troubles with microscopical organisms, tastes and odors.

"Respectfully submitted,

William T. Sedgwick."

This report was generally accepted as establishing the fact, that while there was no occasion for immediate alarm or excessive anxiety, it was imperative that steps should be taken, as soon as practicable, to improve the situation. The epidemics of 1882, 1884 and 1889 were not forgotten, and the figures submitted by me showed a perceptible, though slight, increase of typhoid fever and diarrhœal disturbance during the more recent six-year period. Accordingly,

after still further deliberation, it was decided to extend the intake-pipe some three miles from the sewer outfall into the lake to a point known as Apple-tree Reef, which had been found by repeated bacterial analyses to be a favorable one for the purpose. This extension, as has been fully described in the preceding paper by Mr. Crandall, was made in the summer of 1894. Its completion was undoubtedly hastened by the improved sewerage plan recommended by Mr. Stearns in 1892, and about to be carried out by the Sewer Commissioners, by virtue of which the main sewer outfall would be pushed outward to the lake front, the sewage discharged at all seasons beneath the surface of the lake. As soon as this improvement became assured, Mr. Crandall and the Water Commissioners, as well as the Board of Health, redoubled their activity in urging that the intake of the water supply should be removed further out into the lake, and all the more because the little bay in which at certain seasons the sewage fermented and doubtless worked itself to some extent free from disease germs, was now to be obliterated, so that fresh sewage might at times readily find access to the currents, if any, along the lake front, and at a point less than a mile from the intake of the water works.

I have lately had made by an assistant, Mr. S. C. Prescott, in the laboratory of the Vermont Agricultural Experiment Station—kindly placed at our disposal by Professor Jones, to whom our hearty thanks are due—a series of careful bacterial analyses of water taken from various points on the high service and the low; at the pumping station; from the pump well; and from the lake just outside—a point which corresponds to the old intake; from the lake front near the sewer outfall; and from the new intake on Apple-tree Reef. These show conclusively, both by comparison with analyses made before the extension of the intake and by comparison one with another, that the removal of the intake to a distant point in the lake has caused a marked bacterial improvement in the purity of the city water.

[These facts were then demonstrated to the audience by means of the stereopticon: actual plate "cultures" of equal amounts of water from different parts of the service, from the lake, the sewer outlet, the intake, pump well, etc., grown upon gelatin or agar and fixed by formaldehyde, being placed in the lantern and shown upon the screen. In this way a unique and striking demonstration was

afforded of—for example—the progressive and remarkable disappearance of bacteria from the sewer outlet, where they were abundant, to the old intake, where they were relatively few yet far more numerous than at the new intake or at any point in the service pipes.]

Chemical analyses, as far as they go, confirm the bacterial results, as may be seen from the following:—

Burlington, Vermont, September 4, 1895.

SANITARY WATER ANALYSIS.

(Parts in 100,000.)

	Residue on Evaporation.			Nitrogen.						Oxygen Consumed.	Chlorine.	Hardness.	Iron.	Microscopical Organisms in 100 Cubic Centimeters.		
				Albuminoid Ammonia.												
	Total.	Loss on Ignition.	Fixed.	In Solution.	In Susp'nsion.	Total.	Free Ammonia.	As Nitrites.	As Nitrates.					Diatoms.	Algae.	Blue-Green Algae.
Lake (old intake)	6.60	1.25	5.35	.0110	.0028	.0138	.0010	.0000	.0010	.2730	.14	4.2	.0060	3,550	1,400	200
Tap (city service)	6.20	1.05	5.15	.0072	.0048	.0120	.0000	.0000	.0100	.2496	.10	4.2	.0060	1,050	6,200	150

But there is yet another kind of evidence which witnesses still more eloquently to the improvement of the water supply. This is the testimony of the physicians of Burlington. As far as I have been able to communicate with them—and I have interviewed a number of the most prominent and representative—there is a surprising and remarkable unanimity of opinion among the local physicians to the effect that the peculiar diarrhœal disturbances which had so long prevailed in Burlington have, since the extension of the intake pipe, wholly ceased; and the physicians are enthusiastic in their recognition of the salutary change, which they attribute entirely to the improved water supply.

In view of all the evidence at hand—statistical, bacteriological, chemical and medical—I think we may safely conclude that the sanitary condition of the water supply of Burlington is now most excellent. If, however, in the future Burlington grows extensively and becomes a much larger city it will probably become necessary here, as in most large cities, to face once more the question of a pure

water supply. Special pains must also be taken to see to it that the intake pipe is kept intact and free from leakage. The unfortunate experiences of Toronto and of Buffalo with broken intake pipes afford ample warnings in this direction.

This is the first case within my own experience, now somewhat extensive, in which epidemic diarrhœa in a mild form has prevailed in a community for many years, having its ætiology in the consumption of impure water as has been proved by its apparent total disappearance on a change in the source of supply. The importance of the case in the history of water-borne diseases is manifest. It was complicated by the fact that typhoid fever, which is usually taken as a measure of the sanitary condition of a community, was here ordinarily by no means excessive, and that its occasional prevalence might easily have been due to some other cause than polluted water. The fact seems to be, however, that it was in truth really due to impure water, inasmuch as since the extension of the intake pipe in 1894 typhoid fever has practically disappeared. (See table, p. 175.)

It would seem fair to conclude, from the moderate occurrence of typhoid fever, while diarrhœa abounded, that germs of the latter disease, more hardy than those of the former, were frequently able to survive a journey from the sewer outfall to the water intake while those of typhoid fever, if present, usually perished. In future sanitarians will not be able by the test of typhoid fever alone to show that a water supply is above suspicion. A mild form of diarrhœa caused by polluted water may apparently prevail even in the absence of any constant or considerable excess of typhoid fever.

AN ELECTRICAL PUMPING PLANT.

BY

CHARLES A. HAGUE, C. E., NEW YORK.

[Read Dec. 11th, 1895.]

It is no doubt safe to say that all of us here have first been brought into contact with the pumping question during the age of steam; that age in fact still being in full force and evidence. But during the past comparatively few years, the use of steam in important cases, as in street railway plants, has been relegated to the background, so to speak, and the power required at the exact point of employment has been first converted into the electrical mode of energy. That is to say, in important and prominent directions, the steam power has been concentrated in large plants, where it could be best, most economically, and most conveniently generated; the power given out by the steam engines, converted into energy represented by an electric current, and then distributed to wherever required for useful work.

We have all become accustomed to the terms of horse-power, foot pounds, and pounds pressure to the square inch. The pressure of the steam being susceptible of being actually weighed by a scale, and the result expressed in ordinary terms of force. Then the actual, tangible motion of the steam engine piston, multiplied by the steam force shown by the steam engine indicator, brings to us the measure of the work done. This effect at the steam end of the machine compared with the result shown by a dynamometer, or by a pump delivering water against pressure, at the other, demonstrates the efficiency of the machine as a developer and user of power.

It is of course to be presumed upon the face of the evidence, and will be taken as a fact, that in these huge modern electricity generating plants, in which the power instead of being used directly in the form generated from heat, is transformed into the subtle form known

as the electrical current, that the immense investments of capital are justified by economy and profit. And, in considering this, it becomes apparent that the gain in centralizing power into large plants is not all the benefit derived, but that incidental advantages accrue; therefore the suggestion is born, that possibly in pumping water by the employment of the electric current, the effective economy of the modern steam pumping engine can be so nearly approached, if not surpassed, that in many cases the incidental advantages in using electricity will be sufficient to turn the scale in favor of the electrically driven machine.

The first effect upon the human mind in trying to grasp the points of an alleged improvement, is towards a comparison of the new idea with something already well known; and in considering the pumping of water by electricity, we instinctively grope about in the endeavor to ascertain the exact bearings of the new idea in terms sufficiently near to well known effects, to enable us to make an intelligent comparison. So, as the development of the electrical mode of power began, it was seen at once that the older methods of determining and measuring, must give way to new ones compatible with the elements involved. But the absolute necessity of retaining at least for a time, some vestiges of the older methods, has resulted in an interchangeability of terms which permits the results of the newer school of power, to be compared and reckoned alongside of the older.

Now, coming directly to the point in question, what is the comparison in economy between pumping by means of machinery driven by steam power and that driven by electrical power? Also, what incidental benefits can be gained by using electrical power at the pumps, although at the sacrifice of a certain per centage of the actual steam economy of the engine which might be employed in generating the initial energy?

Answering the first part of the question, or rather the first of the above questions, we must bring the comparison upon common ground, from the standpoint of power developed in each case, and, considering the economy of its development. With the modern steam pumping engine it is probably a fair average to take the efficiency as a machine at 87 per cent.; that is, we can assume that 87 per cent. of the indicated power of the steam end is realized in the work done in the water end. This is with a good average engine, and one of com-

paritively low piston speed, developing a horse-power in every day work with say 14 pounds of steam per horse-power and per hour, or say 16 pounds of steam per pump-horse-power per hour.

In considering the electrically driven pump, the electric current is to be generated in a dynamo driven by a high class stationary engine, and we find that in the transmission of the power it goes from the steam engine into the dynamo; thence in the form of an electric current of a certain potential and quantity by means of a wire into an electrical motor, and there expended in operating the pump. The power of the engine is of course to be indicated in the usual way, but as it leaves the dynamo it is to be measured by "volts," representing our ideas of pressure, and by "amperes," representing the quantity or volume of current, precisely as pounds pressure, and weight of steam consumed, is comprehended in the use of steam. The product of the volts and amperes giving the "watts" will bring us directly to horse-power by dividing by 746. The watts corresponding to our ideas of foot pounds to a certain extent.

Disregarding for the moment the friction of the steam engine, the efficiency of a dynamo may be determined by means of a dynamometer connecting the dynamo to the engine shaft; and a volt meter, and an ampere meter, attached to the conducting wires just beyond the dynamo. The efficiency being expressed in the per centage which the watts reduced to horse-power, bears to the horse-power shown by the dynamometer as being delivered to the dynamo by the steam engine. The reverse of this operation at the motor will indicate the efficiency of that machine; and these several items or factors combined with the indicated horse-power of the engine, and also with the pump horse-power, will give us the following results in comparing efficiencies.

To begin with let us restate the standard by which the comparison is to be made, viz: A steam pumping engine with a mechanical efficiency of 87 per cent., developing a pump horse-power with 16 pounds of steam per hour. The rate of steam consumption in terms of pump horse-power representing the price paid for the mechanical work obtained. The question of boiler efficiency being entirely thrown out of the calculation, as considered upon an equal footing for both sides of the case, although the facilities for handling and stoking fuel in a large electrical generating plant, from which power

could be bought, would give a decided advantage to the electrical view.

The high class steam engine at a comparitively high rate of rotation and at an actually high rate of piston speed, is put down at 91 per cent. mechanical efficiency, and at a rate of steam consumption of eleven pounds of steam per horse-power per hour. It is pretty generally conceded by good authorities that a first-class dynamo properly adapted to its work will give an electro-mechanical efficiency of 95 per cent.; and that an adequate electric motor will do equally as well. The loss of effect in transmitting the electrical form of energy from the dynamo to the motor will depend largely upon the length, size, and condition of the wires; but assuming that the very best of conducting conditions exist, this loss can probably be reckoned at 5 per cent. for an average case when the generating of the power is not in the same building as the pumping machinery. But if we should happen to be operating a specially designed "thermo-electric" pumping engine, so to speak, which the author has in view for the future water works requirements, the loss of conduction could be brought as low as 2 per cent., perhaps still lower. The efficiency of the pumping portion of the machine, reckoning from the point at which the power is delivered by the motor, to the net pump horse-power, is taken at 89 per cent.

It will be seen then that in pumping water under a pressure kept practically uniform, and with a full load, the ideal elements of economy for the multiple-expansion automatic steam engine, and for the generation, the transmission, and use of the electrical mode of energy, are at hand to a very great extent, allowing an extremely close proportioning of steam and electrical apparatus to the object in view. In the modern steam pumping engine there is a constant attempt to compromise to the best advantage between the slowly moving water and the demands of the rapidly moving steam; there being no economy in moving water rapidly, but a good deal in operating the steam part of the machine as quickly as possible, therefore this comparatively new mode of motion, offers some decided advantages in the shape of a mediator between the two well known elements of the pumping problem so far naturally opposed to each other in their association in the same machine. The conclusion which is at least in sight then seems to be to operate the water end of the machine at its best and most economical rate of speed; also give the

steam end the conditions best suited to its thermo-dynamics; and with the electrical element fill in the gap, and so provide a perfectly elastic communication between the two.

To sum up the factors of gain and loss, upon the electrical side of the account, and bring them all into one expression of "rate of steam consumption," in terms of pump horse-power, as representing the price paid for the mechanical work obtained, please note the following:

Efficiency of high class stationery engine	91 per cent.
Steam consumption, per indicated horse-power per hour	11 pounds
Steam consumption per hour per net horse-power	12.07 pounds
Efficiency of the dynamo in delivering to the conducting wires, in the form of electrical energy, the net power given to it by the engine	95 per cent.
Net efficiency of the dynamo as above, in terms of steam per horse power per hour	12.70 pounds
Efficiency of conducting wires in a short circuit, delivering electrical energy to the motor portion of the electrical pumping engine	98 per cent.
Net efficiency of wires as above, in terms of steam per horse-power per hour	12.95 pounds
Efficiency of motor mechanism in transforming electrical energy into mechanical power in pumping engine	95 per cent.
Net efficiency of mechanical power delivered in terms of steam per horse power per hour	13.63 pounds
Possible mechanical efficiency of the pumping part of the machinery	89 per cent.
Net efficiency of the electrical pumping engine under full speed and full load, in terms of steam per horse-power per hour	15.30 pounds

The above result represents about 71 per cent. efficiency of the machine as far as steam consumption compared with useful work is concerned, or in other words, the net pump horse-power is 71 per cent. of the indicated steam horse-power; and from the general idea that 65 per cent. is considered safe in an off-hand statement, it certainly looks as though in the absence of any exact examination of such a plant in operation upon a large scale, that the efficiency herein given is not too high.

If such a showing as that given above could be made with a plant exclusively used for pumping it might be possible to considerably reduce the cost of pumping city water below present current figures,

by utilizing a portion of the steam and electrical machinery employed by some cities for lighting purposes; or, power might be bought from the electric railway and lighting companies; or, still further, where light, power, and water are combined under the control of one corporation, an arrangement of electrical pumping machinery might be made that would be well calculated to effect the general economy of operation for the better. These considerations would come under the second question, concerning the incidental benefits to be gained by the use of the electrical power.

In cities having hilly districts, and where it is necessary to supply residence districts by high service pumping plants, it seems to the author that the electric pump is destined to be of great value. Even in New England, where anthracite coal is largely used, the presence of a tall chimney, however useful it may be, does not add particularly to the appearance of the landscape, to say nothing of the dust and fine ashes liable to be spread broadcast about the neighborhood. But where bituminous coal is used, and soot and smoke are added to the other items of discomfort and uncleanliness, the strong points of the new school of power begin to appear.

For high service pumping the steam power and the dynamo could be operated at the main pumping station, near the water supply, needing in such a case only one boiler plant, and having only one chimney, the electric current being conducted to the upper pumping station. Of course people must have water, and that, no doubt, is the first consideration, smoke or no smoke, but at the same time the very presence and use of water encourages ideas of cleanliness and convenience, until after a while we are educated up to a point of refinement that begins to assert itself against anything that will soil and encumber; even if such annoyances are only a slight penalty we are called upon to pay for the benefits secured. Still if we can keep the benefits and avoid the dirt, and electricity is to be the means of accomplishing such a desirable end, then this item may be set down among the incidentals.

In the high service department the supply goes mostly to residences, and the rate of water per capita in such districts is very much below that of manufacturing and commercial areas; therefore the per centage of the total supply from a main pumping station. represented by the amount necessary for the high service districts, is naturally quite small in most cases. But supposing that it was as

much as 25 per cent., and supposing that in pumping the total supply under a pressure adequate for the delivery of this 25 per cent. at its destination, the power is increased say 50 per cent., it must be obvious that a division of the labor between a main pumping station and a high service station would result in a direct saving of a very considerable difference in coal consumed. Of course there is nothing new in high service pumping stations, as you are aware, but the way the thing is done now is after a high service station has been decided upon to build a complete steam plant, including boilers, chimney, storage for coal, and all of the details necessary for continuous operation and with some idea of future growth.

Here we have then, for supplying our city with water, not only the necessary pumping capacity but also two separate steam generating plants, with two sets of boiler appliances, and two sets of incidental expenses. And not only incidental expenses, but a direct comparison between steam and electricity of real operating costs, touching one or two important items, shows that before long the steam machinery, under some conditions at least, will have all it can do to hold its own. There is not sufficient data as yet to form a definite conclusion as to the relative costs of direct steam and electrical power, but roughly and as far as has been seen, if steam power is generated in large quantities, say 500 horse-power and upwards, the cost line of coal is about $3 per ton, where it begins to pay to buy electricity for power from such plants, for purposes of pumping water.

There is scarcely room to doubt the economy of employing the electrical mode of power for high service pumping, either to buy it from a power or light company, or to generate it at the initial pumping station, and when we consider the fact that the horse-power of pumping engines is comparatively low, and that the fixed charges are abnormaly high, the possibility of cheap electrical pumping in the initial station begins to attract attention. All of the tendencies in the pumping station are in the direction of high cost, and in the large electric station towards low cost. Practically the cost of the same number of attendants is divided by a very small amount of power in one case, and by a very large amount in the other, also the steam cylinder conditions are much in favor of the electric generating plant.

The lowest record known to the writer, for cost of steam power in a large plant of 1,200 horse-power, is $55 for 24 hours operation,

per horse-power per annum. Coal at $1.35 per ton of 2,000 pounds. The cost of the coal was about one-half of the total, so if the coal had been $3 per ton the power would have cost $88; and if the results had been upon the basis of the average pumping engine, the cost of a horse-power per annum would likely have been as high as $140, and at such a rate as that electricity would pay. In the above calculation there are included coal, operating expenses, interest, taxes, insurance, and repairs. There are in this country two large high class pumping engines from two different makers, representing the best probably, all things considered, that can be done at the present state of the art. The most economical one develops a horse-power per annum at a cost of $105, and the least economical one of the two at $87, the most economical being the most expensive to operate on account of the greater fixed charges against a much higher cost of plant. Dropping down the scale, there is little doubt of there being many pumping engines in public service less economical, all things considered, than a good electrical outfit would be.

Now we desire to try the experiment of buying say 400 horse-power from some street railway or lighting company; the first thing to do is to make a comparison between what would be saved by omitting the steam-making part of the plant; and what it would cost for the electrical power. A plant capable of making steam for 400 horse-power all the year through, would require three firemen, which with incidental labor, would cost probably $3,000. Allowing 1.75 pounds of coal per horse-power per hour for all purposes, which you will notice means a pretty high annual duty, the coal at $4 per ton would amount to $12,264 for the year. This added to the cost for attendance as above of $3,000 gives a total of $15,264 as the bare cost of operating the steam making plant. The fixed charges upon the boiler plant, including chimney, storage room for coal, and boiler house, etc., also the fixed charges against the cost of high class steam pumping engine capable of giving a yearly duty as above, as against an electrical pumping engine of considerably lower cost, would be apt to bring the actual cost of power used up to or over $100 per horse power per annum. Against this is the charge for electrical power if from water power, varying from $50 to $80, and if from steam power, varying from $75 to $125 per horse-power per annum.

To put it into other terms we would have a statement as follow-

ing: To the credit of the electric engine, there would be the coal, entire operating expenses, interest, taxes, insurance, repairs, and incidental expenses, including in the calculation all buildings and grounds necessary for the plant. Chargeable against the electrical pumping engine would be the operating expenses, interest, taxes, insurance, repairs, and incidental expenses, including in the calculation buildings and grounds necessary for the plant, and also charge up the electrical power required.

A glance at the above will indicate at once that the fixed charges account would show largely in favor of the electrical outfit, and in the midst of a large city, where a high service station is needed, and where the value of the necessary real estate would be an item worth considering, the electrical pumping engine removes from the field that portion of the plant which takes up by far the most of the room and which is the most troublesome to take care of. In the residence districts of some cities, where isolated service would be desirable, the power taken from an electric wire might be worth, under the circumstances, even $150 per annum per horse-power, in the complete suppression of soft coal smoke, and the curtailment of 50 per cent. of the ground covered, and the buildings necessary, where a good order of architecture would be required.

Another incidental item in favor of the electrical idea is the fact that when less power is used at any part of the day a pro rata amount corresponding to the power shut off is saved, and as there are no fixed charges against the plant when the electricity is bought from an outside company such a saving is net. Electric power contracts can no doubt be made, with a clause providing for the payment for a minimum amount, similar to water meter rates, and then a charge to be made above the minimum amount only as power is used. Also there are many steam pumping plants in operation working under a comparitively low head, so that the fixed charges and incidental expenses are apportioned to a low rate of horse-power, hence the cost of steam power for the pumping would be abnormally high. The author has in mind a pumping plant of about 200 horse-power, with a coal rate of just about 2 pounds, and where the coal and labor accounts amount to $9,870, which brings the cost per horse-power to just about $50 per annum for fuel and labor only. The fixed charges against the boiler plant, boiler house, chimney, coal storage, and coal handling outfit brings the cost of steam generating up to $85 to $90 per annum

per horse-power; other items will carry the rate over $100. The head pumped against is 110 pounds, and if the head happened to be say 60 pounds with the same attendance, as the pumping is continuous, the cost per horse-power would increase, because the fuel saved would not be in direct proportion to the decrease in power, the economy would not be quite as good, and the incidental expenses would not drop very much; but in comparing two such plants operated by electricity, the reduction in power would reflect a tangible fall in the cost of running.

Of course the question will naturally rise, that, if a certain power is to be used in pumping, and this power is to be developed by steam, why can it be delivered through the electric current at any advantage to the user? The answer is in two sections; first in reducing the pump friction to the lowest terms by moderate speed in moving the water, coupled to a high speeded steam factor of small dimensions, the electricity forming the bond between them; and second in buying the power needed in pumping, from an establishment making a business of generating the power in very large units by means of multiple expansion engines at high piston speed as compared to a slow working pumping engine; the expenses of attendance and labor being very much less per horse-power in a unit of 2,000 than in a unit of 200; it also being remembered that the larger plant admits of the use of fuel-distributing and stoking machiney, heat economizers, boiler-feeding apparatus, etc., upon a scale not admissible in the smaller plant; such facilities reducing the cost of steam and power-making to a very great extent. In the above references you will observe that very high annual economy is calculated upon; but supposing that we drop right down to the annual duty actually shown by many official reports, in which the coal consumed goes up to or over 3 pounds per horse-power per hour; we shall find that even now electrical energy could come as high as $130 per horse-power per annum with a profit to the buyer, to say nothing about incidental benefits.

With reference to water-power for generating the electric current, and by conduction, realize the energy at some distance, it has heretofore been held, previous to these days of the electrical mode of energy, that it did not pay to go very far out of the way to secure the benefits of water-power, because the near approach to the utmost economy in the steam engine reduced the cost of producing power so low that other advantages in the shape of convenience and acces-

sibility of markets, both for raw material and finished product, were of more importance than the entire question of the cost of power. But today, instead of transporting materials to the location of the water power, and carrying the finished products of manufacture to market, the power can be generated at the natural water head, and in the form of a high tension current of electrical energy, can be transmitted to any desired point within a reasonable distance, reduced in voltage if desired, and then utilized.

Probably the cost of plant, including dams, water wheels, penstocks, tail races, and other details, may carry the investment of capital per horse-power in the water power plant as high, or higher, than the necessary investment in a modern steam power plant. Even if the use of water power does cut out the fuel account, the investment in the conducting wires from the source of the water power to the place of employment represents to some extent an offset in the form of interest account, to the value of the fuel saved. From this it will appear that there are several matters to be known, before a decision can be reached as to the relative economy between steam and water power, although upon general principles the water power ought to succeed in the competition, when coal costs say $3 and upwards per ton, and when the water power is not to exceed 25 miles away from the point where the power is wanted. It must be borne in mind that the reliability of the stream furnishing the power must be unquestioned, or we may be obliged to go to the expense of an additional investment in auxiliary steam plant, which might destroy all of the seeming advantages of the cheap water power. The electrical storage battery is no doubt destined to play an important part in the using of the electrical mode of energy, as in this very question of water power, at night when factories are stopped, and the water may be largely going to waste, the generation and storage of the electrical motive force could go on through the night, until the demands for water for other power began again. Of course in dry times like the past summer where the accumulation of the water at night while the mills were at rest was only sufficient to insure a full day's power following, the storage battery could not be employed, but such seasons are exceptional, particularly as to being so widespread as in 1895.

The storage battery would apparently be a potent means of reducing the price at which power companies could afford to sell energy for

pumping purposes, as by its use the great bulk of the fixed charges could be materially reduced, providing as it does adequate means for operating the power and generating machinery at its fullest or most economical capacity 144 hours per week, and the full seven days if necessary. If the storage battery is an improvement the Germans are ahead of us, as more than three-quarters of the central power stations in that country are provided with this appliance. In public water supply, by electrical pumping machinery, the storage battery would take away the apparent risk of depending for a water supply, upon what appears to be a very slender copper wire, a consideration which would be of some weight, no doubt, to fire underwriters.

The pumping of water by means of the electrical mode of energy is very likely destined to play an important part in the future of public water supply, and the standard pump makers are already endeavoring to reconcile the differences which attended the first attempts to operate pumping machinery by electricity. Differences made apparent by the electricians' idea that any kind of a pump could be operated by attaching a motor to it, and by the pump makers' idea that any sort of a dynamo could be used in running a pump. The entire question illustrating the fact that the office of the mechanical engineer is to adjust and adapt to the conditions in hand, and objects in view, the forces of nature applied to useful effects.

DISCUSSION.

MR. BARRUS. I cordially agree with Mr. Hague that there are incidental benefits to be gained by using electrical power for pumping, and that in some situations, such as for high service pumping stations which he mentions, and, no doubt, for many other situations, the total cost of pumping water by the use of electricity is likely to be less than that due to the methods in vogue at the present time. I have in mind the case of a mill now in course of erection where the water for the industrial purposes required in the factory is to be obtained from a brook about half a mile distant. An electric plant is to be installed in the engine room of the mill, and an electric pump supplied with current from this plant is to be placed at a point near the brook. Between this arrangement and that of an independent pumping plant, with boiler, chimney, and supply of coal, and the necessity of constant attendance of an engineer to operate it, there

can be little question that electricity provides the best method for accomplishing the object. The adaptability of electricity to pumping water, it seems to me, follows the same laws as its application to the production of power for any other purpose, and it depends wholly upon the circumstances. I believe it is fairly well settled that it will not pay to transmit power electrically where the machinery to be driven is in close proximity to the generating plant, such as would be the case in an ordinary mill, or in ordinary pumping stations. I do not mean by this statement that it would not pay to transmit power by electricity in such a situation, whether it be in a mill or in a pumping plant, provided the current was obtained from a large central electric plant at a price far below the cost of producing the current in an isolated plant, but the statement applies simply to the generation of the current by an independent plant which is to be erected for the purpose in hand. I think any engineer at all familiar with the subject will bear out this assertion.

As to the general subject, and the relative economy of steam consumed in the two processes, it seems to me that there is some ground for criticising Mr. Hague's calculations. In his computations he makes out that the steam consumed by the electric pump per horse-power per hour of water delivered is 15.3 lbs., as against a consumption of 16 lbs. in the case of the mechanically driven pump. One of the elements upon which this comparison is based is the assumption that in the electric plant the steam used per indicated horse-power of the driving engine per hour is 11 lbs., while in the mechanically driven-pump the consumption is put down at 14 lbs. I do not think I am wrong in saying that pumping engines have realized as high economy in steam consumption as any engine used in the production of mechanical power in spite of the fact that the pumping engine operates at relatively slow speed. I have in my own work obtained as high economy from a pumping engine running at 20 revolutions per minute, as from a triple expansion mill engine of large size making 70 revolutions per minute, and there is good ground for the belief that the published records obtained by other parties on this subject are reliable. These show the same fact, namely, that the power developed in the steam cylinder of a pumping engine can be produced with as small a consumption of steam as that produced in the steam cylinder of an engine driving an electric generator. I fail to understand, therefore, what ground there is in this paper for

assuming any such difference of economy in favor of the electrical pump as that stated. I see no reason why there should not be an equality in the quantities assumed, in which case, according to my calculations, the cost of electrical power expressed in terms of steam per pump horse-power per hour would be some 20 per cent. more than that produced by the mechanically driven pump.

It is of little consequence, however, whether these assumptions and calculations are correct or not, for the question of the use of electricity for pumping in any individual case will depend altogether upon the local conditions, as is well stated in the paper. There is no doubt that there is a wide field for the application of electricity in water works service. It is well to bear in mind that the time is probably coming when towns and cities will not only own and operate their own water works to a larger extent than is done at present, but they will also come into possession of the electric plants now in use for lighting purposes, or install their own for the necessary work of the town or city. It is easy to foresee that when this condition of things is brought about, and especially where new plants are to be installed for these two purposes, that many cases will arise where it will seem expedient to provide a central station of sufficient capacity to generate electricity, not only for the lighting, but for pumping water, and establish at the point of water supply an electric pumping plant in place of a complete steam plant, thereby securing the benefits which attend the generation of steam and the production of power at a single station.

MR. HAZEN. I have listened to the paper of Mr. Hague with great interest, and to the discussion of it by Mr. Barrus. There seems to be a sort of fascination in the word "electric." We hear of electric medicines, and of electrical processes for doing this or that in which in reality there is no electricity except in the name itself. But here seems to be a case where electricity has a new use, or at least a new application, and I think we should all like to hear from Mr. Dean himself as to what he thinks of the process mentioned in the paper which he has read, that is as to its adaptability, practicability, etc.

MR. DEAN. Mr. Hague lays himself open to rather severe criticism in some of the assumptions which he has made in his paper, and which, I think, if properly stated would lead to different con-

clusions. I think Mr. Barrus has stated the matter pretty nearly right. There are a great many cases, of course, where it may be advisable to use electricity, but I think that the figures which Mr. Hague has given are likely to mislead and I should be very sorry to have them go unchallenged.

Of course I am rather more likely to notice the steam features of his paper than the electrical ones. As to the adaptability of electricity, it can be transmitted from one place to another without any difficulty, and you can make it as economical as you choose, and you can make it pump water. And I think any man, if he had a case at hand, at a high service pumping station, for instance, could very quickly come to a conclusion as to whether he had better drive pumps by electricity or establish an independent steam pump. As Mr. Hague says, many fixed charges would be very much reduced by the substitution of electricity for direct steam.

I am a little puzzled at Mr. Hague's paper, because in some places he seems to give estimates unduly favorable to the steam pumping engine, and at other times quite the opposite. He speaks of the efficiencies of pumping engines as being about 87 per cent. of the power developed at the steam end, while there are a great many cases in pumping engines of the kind that Mr. Hague has been so closely connected with in late years, and also in others that differ from them very much, in which the efficiency is above 87 per cent. For instance, at Lowell the high duty Worthington pumping engine gave an efficiency of 97 per cent. That engine was tested by Mr. Barrus, and the test was sufficiently long to give a virtual duplication of results, so that nobody could reasonably doubt it. Then, at the Manchester water works I obtained an efficiency of 94 per cent. from the same kind of engine. At Louisville, the fly-wheel Leavitt engine, which is very heavy, gave an efficiency of 93, and at Newton the Blake engine gave 92. The old Morris engine at Lowell, which I have tested twice within two years, has given 97.36 and 97.51 per cent., and the celebrated Allis engine at Milwaukee gave 91 per cent. efficiency.

At the steam end of the pumping engine Mr. Hague takes the steam consumption at 14 pounds of steam per horse-power per hour, and 16 pounds per pump horse-power per hour; and he takes the high speed engine, with which he proposes to drive his electrical

generator, as using 11 pounds of steam per horse-power per hour, and claims that in consequence of the high speed of the possible engine driving the electric apparatus, the great economy of 11 pounds of steam is attained.

It seems to me that there is nothing more delusive than this speed idea, because it happens that about all of our economical consumptions of steam in steam engines are obtained from pumping engines. And while quick reciprocation gives less time for condensation to take place, it does seem as if the desire of a steam engine to condense steam is greater than the possibility of the steam to overtake it. I believe I am right in saying that there are not over two engines in the world that use as little as 11 pounds of steam per horse-power per hour, and possibly only one. It may be that the Leavitt pumping engine at Chestnut Hill in Boston will show as low as 11 pounds of steam per horse-power per hour when the engine is perfectly broken in, and the steam working parts have become smoothed down and everything is perfectly tight.

It has been reported in various papers that a small engine in Germany, known as the Schmidt motor, tested by Prof. Schröter, of Munich,* a very reliable man, has used as little as 10.17 pounds. But that engine used steam which was superheated to nearly 300 degrees, and, as you know the great enemy of economy is steam condensation, this great superheating of the steam prevented condensation from taking place. But the persistency of the tendency of steam to condense is illustrated well in this case, for when the steam left the cylinder of the engine it was ordinary steam, and this great superheat had left it. Superheated steam is the hope of the future in economy, but it is something which vanishes with great rapidity.

There is only one engine, so far as I know, which seems to be benefitted by high speed, and it is difficult to determine in that case whether it is the high speed, or some of its many other admirable features, which account for its economy. I refer to the Willans engine. It is an English engine, but has now been taken up in this country by the M. C. Bullock Manufacturing Co. of Chicago.

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*See *Engineering*, Vol. LIX., 1895.

Then, coming to the pump end of the electrical apparatus, Mr Hague takes the efficiency of that as 89 per cent., that is to say taking the efficiency of motor and engine together, he gives it as 89 per cent. That is slightly higher than he takes the efficiency of the pumping engine. But the connection between the motor and the pump would very likely be through gears, and of course the efficiency of gears is low, and it is rather difficult for me to see how he can take the efficiency of such a combination higher than he takes that of the ordinary pumping engine.

Now, by starting with an extremely economical and hypothetical engine, for such a one does not now exist, Mr. Hague finally comes to a consumption with an electrical plant of 15.3 pounds of steam per pump horse-power; whereas, if he had started with a probable and contemporaneous engine, using say 13 pounds, he would have arrived at about 18 pounds at the pump end. And, coming back again to the matter of steam consumption, while I stated the efficiency of various engines, I will now state their steam consumption per pump horse-power: Louisville, 13.05; Newton, 15.25; Lowell, Worthington, 16.58; Manchester, Worthington, 19.76; and the Milwaukee, Allis, 13, the Allis being the lowest.

There is another factor to be considered when it is proposed to buy electricity from a street railway or from a lighting plant. If such a company were to sell electricity to a city for pumping they would have an advantage, if they chose to profit by it, of having a steady power, and therefore the engine which they used might very well be proportioned to do its work at the most economical rate, and therefore the city would be entitled to the lowest price per horse-power per hour. But street railway plants are very wasteful indeed, because the power is everything; it is all the way from zero to the maximum. And so at Milwaukee, even with a triple-expansion engine, which should have used as low as 13 pounds of steam per horse-power per hour, the fact is they use over 18. Now, if you can make a street railway company distinguish between the economy of your part of the plant and that of their own part, you will do better than I think you can. I think they would charge you as high a rate as they charge for any of the rest of it. And they are not content with small profits. I recently had a case in which a street railway company wanted to sell power for a certain purpose, and I was asked to obtain for them the cost of the power, and I

then added what I thought ought to be a proper, or at least—yes, a proper profit; I added 15 per cent. as the profit to them, and they were astonished at the lowness of it, and I judged from their conversation that they wanted 100 per cent. profit instead of 15.

It seems to me that the suggestion that Mr. Leavitt made when he read his paper before this association a year ago last summer, that at the pumping station there is to be in the future an electrical plant for the various purposes for which a city needs it, is the thing that is coming to the help of the city wherever it needs a small power at a distance. The pumping plant and the electrical plant for lighting the city will very likely be in the same place, and in that case the fixed charges could be very considerably reduced.

In regard to water power, Mr. Hague mentions a difficulty. It is very seldom that a water power is worth having, for the reason that it is very unsteady. Sometimes there isn't water enough, and at other times there is too much, so that the power is inadequate, and that means a spare steam plant, with all that goes on with it for fixed charges. And then again there comes the reduced efficiency of waterwheels by getting all sorts of things in them, and anchor ice, and the employment of a special man to fish out the anchor ice, leaves, etc.

The depreciation of an electrical pumping plant is probably greater, I have no doubt it is greater than that of a steam plant—perhaps 7 or 8 per cent. depreciation instead of say about 4 for a pumping engine.

Finally, it is, I should say, perfectly practicable to use electricity in this way, and whenever a case comes up I have no doubt that the engineer in charge will come to proper conclusions in regard to it. You can do pretty much anything with electricity, but it is something that is very much over-rated. It is being quacked about as being a cure for everything. We hear it said that electric locomotives are going to double the speed of steam locomotives. But the people who talk that way have no idea of the limitations of speed, they don't know how train resistance increases, and what they say is generally worthless. There seems to be in connection with the electric companies a bureau for the dissimination of useless knowledge, which appears in all the newspapers. (Laughter and applause.)

Mr. Crandall. I would like to ask if 5 per cent., the amount

which Mr. Hague mentions as the loss in the conductor, isn't very much less than is ordinarily encountered, on account of the cost of a conductor which would effect only that amount of loss.

Mr. Dean. I feel I am assuming a great deal in attempting to discuss electrical matters, as I know probably as little about electricity as any one here present. I thought Mr. Hague had taken the electrical losses as very small, and beyond that I cannot say anything.

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WATER-BORNE DISEASES.

BY

DR. THEOBALD SMITH,

Pathologist of the Massachusetts State Board of Health.

[Read January 8th, 1896.]

MR. PRESIDENT AND GENTLEMEN: In the consideration of problems pertaining to the protection of the public health two facts must be kept constantly in view: first, the increasing density of population; and second, the continual movement of the population. The dangers due to infectious disease germs are thereby slowly augmented by importation and by the difficulty of tracing outbreaks. A further danger is the increase of squalor in large centers of population, which favors the direct transmission of disease germs from one person to another. Hence the watchfulness of public health officials must continue to grow rather than to relax, and the laws and regulations designed to maintain public health must become more and more rigid. The movement of scientific discovery does not tend towards the establishment of an automatic public health machine, but insists on greater care, greater watchfulness, more restriction, more expenditure, and more training on the part of those entrusted with this work, simply because of a growing complexity of the social

organism. Possibly some great war would furnish a splendid opportunity for us to see the dogs of disease let loose on the community. The increase of typhoid, the spread of small-pox, the importation of cholera and the appearance of typhus and new diseases would show what we do not now see so plainly in times of peace, the great but quiet and mostly frictionless work of sanitary organization in holding the reins of a number of restive disease germs, whose power over society is by no means extinct, but on the other hand, even greater than before, owing to a certain deterioration of the physical man whose vigor is paid as a price for our civilization.

Water as an important food of the human race is peculiarly liable to deterioration under prevailing conditions, and must of necessity demand increasing watchfulness and a continual readjustment of restrictions governing its use. Its dangers differ from those of other foods in several respects. It is above all a raw food, while perhaps five-sixths of all our other food is sterilized before use. Again, it is a vehicle which drains large territories, and hence may bring together disease germs from a large watershed. It plants its foci of disease throughout a city, and the subsequent extension of such foci will depend upon various factors. In an over-crowded tenement one case of disease may give rise to many others by direct infection. In the home of the well-to-do every precaution is taken to isolate the patient, to disinfect the feces, and thus to prevent an extension of the disease to others in the household or to the water courses, which, unfortunately, are only too often the sources of drinking water for other communities.

The importance of drinking water for good or for evil is not underestimated nowadays, and the activity of investigators the world over is something phenomenal, and will probably continue so in the future. It is my intention today to present among a few new facts mainly such as are already well known. There is always much skepticism concerning current facts, and a reiteration of the more important ones from slightly different points of view with additional proofs is likely to remove skepticism and promote their practical application.

Investigations up to the present have strengthened more and more the standpoint that water is a carrier of certain infectious diseases, having their primary seat in the digestive tract. They furthermore have shown that water is not the only primary carrier of these dis-

eases, and that other agencies, such as raw foods, may be concerned. Furthermore, direct infection from person to person probably plays a much more important part than has hitherto been assumed. Water, therefore, has its place among the carriers of certain infections, but not a supreme or an exclusive place, and this should be kept carefully before us. It is probably not at all concerned in the distribution of many infectious diseases, such as tuberculosis, diphtheria and the eruptive diseases. Evidence is pretty conclusive that micro-organisms producing typhoid, Asiatic cholera, dysentery and diarrhœal diseases are often carried in drinking water.

As an illustration, let us take Asiatic cholera, not because it is likely to invade our territory in the near future, but because as an exotic disease its dissemination is more easily traced than a disease like typhoid, with which civilized countries are now saturated.

The localistic theory of Pettenkofer, with which you are perhaps all familiar, made the ground a certain factor in the development of the pathogenic properties of the cholera germ. Basing himself on an immense amount of statistical evidence, he found that certain towns were insusceptible to this disease, and others were always attacked when the opportunity was offered. From these facts he concluded that the cholera germ had to undergo certain changes in the environment, more particularly the soil, before it became infectious again, and that certain localities were better fitted than others to produce these changes. When Koch began his investigations of cholera, his biological training took him in a different direction. He was led to consider cholera as a contagious disease, transmissible from one person to another, and from one community to another, without any intermediate preparatory changes in the soil or in the water. This view he pushed with a great deal of energy in spite of much opposition. It is mainly to his efforts that the view that water may be a vehicle of infection is now predominant. Although that view was held more or less before his time, yet he was its most vigorous supporter and presented the largest number of facts in its defence.

The view held by Koch that the primary vehicle of the cholera spirillum is water, was quite thoroughly confirmed by the Hamburg epidemic of 1892. To ward off the persistent encroachments of this disease since then, the German government made extensive efforts in 1893 and 1894 along the lines laid down by Koch to suppress the

disease along its boundaries. Bacteriological laboratories were busy during the summer months examining thousands of specimens of water and of stools to trace the presence and the movements of the cholera germs. One important fact discovered by this extensive investigation is that cholera travels mainly along the river courses. It was found that it moves up the river, and that the carriers of the germ were mainly people who are engaged upon the river and who drink water from it. Some cases very strikingly demonstrated this view. One mentioned in the official reports is that of a boy who fell into the river at Berlin and swallowed a considerable quantity of water, and who, although perfectly well at the time of the accident, was taken down with cholera on the following day. This occurrence may be regarded equivalent to a laboratory demonstration of the function which drinking water bears when cholera is prevalent.

By the energetic measures of the German government, cholera was stopped from traveling far beyond the boundaries of the empire, and this success was simply due to the fact that water courses were regarded as the primary carriers of infection, and that persons who moved back and forth on the rivers were carefully watched, and at the first indications of disease quarantined.

The transmission of typhoid fever has been very much discussed of recent years. It is endemic in all civilized countries, and hence occupies the attention of sanitarians to a large degree. It also is a disease which may be carried by water. The conditions favoring the dissemination of typhoid are much more complicated than those favoring cholera, because the infection is present everywhere, and carried by people who are likely to deposit it in various places before it is known, and by whom an epidemic may be started without any recognition of the source of infection on the part of health authorities. The tracing of typhoid outbreaks will be more and more complicated in the future unless recent bacteriological developments help us in the study of this disease—that is to say, enable us to determine the presence of these bacteria in the intestinal tract of human beings and in water. Our inability to do this has been our difficulty in the past. But I shall refer to this matter again in the course of my remarks.

There are two other water-borne diseases not at all uncommon in civilized countries which cause a great deal of trouble in a small way —I refer to diarrhœal and dysenteric diseases. There is no doubt

that they may be conveyed by water, and probably are largely so conveyed. But there are other causes of such troubles that may be overlooked. One of them is the infection of milk; another is the infection of meat with the disease germs of animals.

If we take a general survey of the subject of water as a carrier of infection we will discern what most of us have held for a number of years, that all sewage-polluted water must be regarded as dangerous, whether there is any active typhoid on the watershed or not. It is highly probable that the water receiving the sewage of large communities always contains the typhoid fever germ in larger or smaller numbers, because in large cities typhoid fever does not seem to die out completely at any time. We have as an illustration a city not very far from here, in an adjoining state, which has long drawn its water supply from a large river, which receives the sewage of forty or fifty thousand people six miles above its intake. I had something to do with the examination of the water four or five years ago, and the number of fecal bacteria in that water was very large. As a result the typhoid mortality is very high. Four years ago not only was typhoid very extensive, presenting such various forms that physicians were often in doubt as to the diagnosis, but there appeared simultaneously a winter epidemic of diarrhœal diseases which was undoubtedly favored by the concentration of the sewage-polluted water in the winter months.

The argument which people who use such water present is usually that they have drunk the water for thirty or forty years and are still well. This argument which is presented to us at all times is based on a number of fallacies. In the first place, there is a popular conception, which it is difficult to eradicate, that the water itself deteriorates, and not that something infectious is put into it, which may be put into it in larger and larger numbers as the concentration of the population increases. It seems to me that a campaign of education on the subject of germ diseases amongst those people who have charge of the affairs of our cities, would be most valuable and most timely. They do not realize that the population is continually increasing, that there is a continual movement of population by which disease is brought from outside and the water infected long before suspicion is aroused. Nor is it sufficiently appreciated that many persons who drink polluted water are not affected because they are

insusceptible, or because they have become vaccinated or protected by mild attacks which were not recognized as typhoid.

Another disease which has been considered as water-borne is malaria. This disease, of course, arouses considerable interest nowadays, because it has slowly extended into communities which were hitherto free from it. The literature of the subject is voluminous, and the writers divide themselves into several camps, one of them claiming that malaria can be carried by water, another that it cannot, and a third that water is one of the carriers among several. In general it seems to me, after reading much that has been written upon the subject in medical journals, that those who hold that water is not the carrier of malaria have the better of the argument at the present time. Malaria is a disease which is caused by a specialized disease germ. This lives in the red blood corpuscles, and probably cannot live outside of them, excepting under very special conditions. I doubt very much whether such a germ can have two ways of entering the body, and I think that it probably has developed for itself one way which it must follow or remain outside of the body. If it can be shown, as I think it has been shown abundantly, that malaria is contracted when drinking water is not implicated, I believe that that fact is almost of itself sufficient, until positive evidence is at hand, to counterbalance the argument that malaria is carried in water. There is one thing which largely defeats our observations on the subject of malaria, not so much in this climate as in the climates further south, and that is the latency of the disease in the human body. It is probable that in the southern malarial countries the greater number of people carry the malarial germ in their bodies without any recognizable external manifestations of the disease. Just as soon as such persons expose themselves in one way or another, by indiscretion at the table, by exposure, or by overwork, the malaria appears, not because the infection takes place at that time, but because the infection which had taken place at some distant time was able to gain the upper hand.

Dr. Smart, of the army, who favors the theory that water is a carrier of malaria, writes to a medical journal recently that some of the forts in the south have been greatly improved by the introduction of pure drinking water—distilled water, for instance—and that the number of cases of malaria have been very greatly reduced by this

change. Here, however, permanent infection of the blood cannot be excluded owing to the sub-tropical climate of the stations. Impure water in such cases may act as an exciting cause, by disturbing the digestion, by producing diarrhœal troubles, and thereby give the malarial germ an opportunity to exert its pernicious influence.

If we accept, then, the postulate that drinking water is a vehicle for certain infectious diseases, sometimes denominated filth diseases, we may pass to the question, What means are at hand for estimating the potential or actual dangers of any water supply? We have at least three ways of estimating the sanitary condition of a water. We have, in the first place, inspection; second, the chemical analysis, and third, the bacteriological analysis. Now, I shall not, of course, refer to the matter of inspection, because that is a question which need not be discussed, nor shall I consider the matter of chemical analysis. I wish to limit myself entirely to the question of bacteriological analysis as directed towards the determination of the sanitary condition of a water.

When Koch first discovered, so to speak, the gelatine plate method, he set to work to determine the number of bacteria in various waters. His work established the rule for a time that the number of bacteria in water, as determined by their growth on gelatine plates, was in a way indicative of the relative amount of pollution in the water. This method of numerical determination was carried on for some time, until a current set in against it. Then followed the study of pathogenic germs in water, that is to say, the study of methods by which the pathogenic germs, which are directly concerned with disease, can be brought to light.

From my own point of view I believe that the numerical determination of bacteria in water is of very great value. The main difficulty up to the present has been that we have had insufficient data with which to interpret the results of the bacteriological examination. It was hoped when this method was brought out that any half hour examination would give us full information concerning the quality of the water examined. But this view, of course, which was very superficial, has entirely given way to the view that much more is to be done bacteriologically before we can say anything concerning a water.

The numerical determination of bacteria in water for sanitary purposes is of very great value in surface waters, lakes and rivers,

especially the larger rivers. I believe that up to a certain point the number of bacteria is proportional to the pollution of a river—we cannot say exactly fecal pollution, but it may be pollution from dead organic matter of one kind or another. Thus a dead animal thrown into a stream may for a short time change the bacteriological condition quite materially. The same may be said of all organic impurities of an animal nature, the feces of animals as well as those of human beings. I think that the important thing which should be done at present is to have numerical determinations of bacteria in our large water supplies put on record either daily or semiweekly. Such a record should be kept for future use, because in the hands of a skilled biologist the interpretation will be very valuable, certainly as valuable as any chemical analysis is ever likely to be. The information to be gained by the periodic counting of bacteria in water is best shown by some illustrations.

For a number of years, beginning in 1884, I had taken considerable interest in the bacteriology of the Potomac water which supplies Washington, and I found year by year that the bacterial curve was almost constant. This curve is peculiar in this, that the number of bacteria is high in winter and falls quite low in midsummer. Another fact of importance is that whenever the water became turbid, which is a characteristic of the Potomac supply after rains, the number of bacteria rose very abruptly. There was a definite relation traceable between the number of bacteria and the suspended matter, so that after a little experience I was able to estimate approximately the number of bacteria in the water by an ocular inspection of the turbidity.

It should be stated, however, that this bacterial curve does not correspond to the typhoid fever curve. The latter is highest in late summer and early autumn, when the former is lowest. The apparent contradiction remains to be explained. It may be attributed to the large importation of typhoid from unsanitary suburbs and summer resorts, possibly to the extensive use of water from the many city wells. The Potomac receives comparatively little sewage, yet the conditions are such that this slight pollution may prove very telling at times when the system is most susceptible and when water is drunk most freely.

Profs. Brown and Stoller, of Union college, made, several years ago, extensive observations on the number of bacteria in the Hudson

river. Taking samples far above sources of pollution, they found the number very low, not much above 50 in a cubic centimeter, I believe. Going down stream the number steadily rose until, below Albany, it reached the figure of 30,000 to 40,000 at times.

The numerical determination is also of importance in tracing imperfections and leaks in a water supply. Perhaps some of you remember the paper of Dr. Shuttleworth, of Toronto. He had studied the water of the lake from which the water supply was taken pretty thoroughly bacteriologically, and from his examinations he decided that something was wrong in the water supply, as the bacteria were growing more numerous. Finally the city authorities were stirred up to look into the matter, and found that a whole section of the conduit had dropped out of place in the water near the shore, and that the supply was therefore being taken from near the shore instead of some distance away where the intake was located.

For wells the interpretation of numbers is not so easy, largely because most of the infection enters at the surface. Wells which are poorly protected at the top will always show a pretty large number of bacteria. This fact I was convinced of by the examination of a large number of wells in Washington. I may state, for the benefit of those of you who are not familiar with that city, that it has over 200 wells distributed throughout the city, which were constructed when the water supply was inadequate, and which are still in use. They are cherished by the population, and if one happens to be removed an appeal to the health officer not infrequently leads to its restoration. I recall one in which I found fecal bacteria several times. The well was closed up, then reopened on account of the clamor of the people living near it, and finally the pump was removed. I was at times struck with the purity (bacteriologically speaking) of some of the well water in the heart of the city, where the surface is quite thoroughly protected from pollution by the asphalt pavement, which prevents the urine and feces of horses from entering the grouud. Sometimes I could find not more than from four to twelve bacteria in a cubic centimeter. In other cases, where there was evidently leakage from the surface, the number would run up to 500 and 1,000 in a cubic centimeter.

We all know of what immense value the numerical estimate of bacteria is in determining the efficiency of filters. I will not dis-

cuss this phase of the subject, because there are others here who are better prepared than I am.

Let us now turn briefly to a consideration of the search for pathogenic germs which produce specific diseases, such as typhoid and cholera. I am glad to say that the cholera germ, if it should ever come into this country, can be quite readily detected. The methods of bacteriology have been so advanced in recent years that by certain processes of cultivation the cholera germ may be detected even where it is present in very small numbers in water or stools. Thanks to these methods it was possible to examine thousands of fecal discharges and samples of water from the basin of the Oder, the Vistula and the Elbe in Germany during the past two years, in order to trace the presence of these germs in water, and in the fecal discharges of patients and suspects. It was found by these methods that a great many persons who lived in infected families carried the cholera germ in their intestines without being ill. This point I consider of very great value. It is a matter which one might have anticipated from a bacteriological standpoint some years ago, but now it has been satisfactorily demonstrated. The cholera germ can be carried by persons who are apparently healthy from one place to another and discharged with sewage into streams where multiplication is to all appearances possible.

With typhoid the conditions are much more complex, for, as you may know, the typhoid germ has been confounded with ordinary fecal bacteria for some years past. The frequent announcements of the detection of typhoid bacilli in water are now generally regarded as false alarms. However, the non-discovery of typhoid bacilli does not mean their non-existence. Until satisfactory processes have been worked out, the suspicion of typhoid infection must rest upon other facts than the detection of typhoid bacilli. Very recently a method has been suggested which may eventually solve the difficulty. It consists in adding a little potassium iodide to gelatine plates, by which the typhoid germs in fecal discharges are brought out without much difficulty. This method may be useful in determining typhoid bacilli in persons in whom typhoid might be suspected, but in whom definite symptoms are lacking and who are not very ill. One of the prominent workers on infectious diseases in Berlin (Brieger) has recently stated that the method has worked very well in making the diagnosis of typhoid in cases in which it

could not have been made clinically. We shall all look forward with interest to the more extended trial of this new method, especially in the recognition of mild attacks of typhoid fever, and in the persistence of these bacilli in the stools of convalescents and recovered cases. A knowledge of these things is quite essential in tracing the origin of epidemics and their relation to drinking water.

We may now approach the question how we shall determine the amount of pollution in water, leaving aside the presence of pathogenic bacteria. One of the methods which I have used for a number of years is to determine the number of colon bacilli, those bacilli which inhabit the intestinal tract of men and animals almost exclusively. It has been claimed that colon bacilli flourish outside of the intestines. It is true that they are widely distributed in nature, mainly because fecal discharges of human beings and animals are a common thing on the soil. The method which I have used consists in determining the presence of colon bacilli in water by their power of fermenting sugar. This test has been so satisfactory that I apply it whenever the opportunity presents. Large quantities of water may be used, a thing which is quite impossible with solid culture media, owing to the softening of the media.

But what is of especial importance is not simply to find the colon bacillus, for this may be found in almost any surface water, however pure, if enough water be taken for the examination, because animal life is everywhere. A bird passing across a stream may drop colon bacilli into the water. We know that they are present in the intestines of human beings, dogs, cats, sheep, cattle and swine. Hence the mere presence of the colon bacillus does not necessarily mean pollution with human excrement, nor does it mean that the water should not be used. What we do wish to find out is *how many* colon bacilli are in a given quantity of water, and I think if records of this sort were kept the increase or decrease in pollution might be traced week by week, month by month and year by year with a great deal of accuracy. Any sudden leakage of sewage into conduits or any injury to the latter might be discovered by such records. Prof. Jordan, of the Chicago University, found that the typhoid bacillus did not multiply in water, but the colon bacillus did. He tried water, however, from which he had eliminated all competitive bacteria, so that the question still remains, Will the colon bacillus multiply in ordinary water, which is already occupied

by a large number of water bacteria? If it multiplies abundantly, it would to a certain degree vitiate the test I have described. I am inclined to believe until proof to the contrary is forthcoming that colon bacilli do not multiply to any extent in water under natural conditions. The numerical estimate of *bacillus coli* in wells, it seems to me, would also be of great importance as denoting pollution, especially in country districts where the water is used in connection with dairies.

I wish to say a concluding word in regard to preventive measures. What can be done in case a water supply is infected? In regard to wells the problem is not so difficult. A number of years ago some German investigators tried lime, and found that to be fairly effective. They also tried a mixture of carbolic and sulphuric acid, and found that would sterilize a well; but these are very objectionable substances. More recently from the same quarter there has been suggested a method of injecting steam under a pressure of two atmospheres. This is forced into the water till the temperature is brought up to nearly the boiling point. The hot water destroys pathogenic organisms and, as it were, sterilizes the well. In reservoirs this treatment is not feasible. In such cases those using the water should boil it for a certain length of time. This is the safest method since pathogenic bacteria perish in water probably after two or three months at the longest.

In conclusion I wish to urge upon you the significance of mild cases of typhoid in starting infections, and the necessity for keeping a record of the numbers of bacteria and of the relative frequency of the colon bacillus in our water supplies. These suggestions are not so easily carried out, for they require more or less expenditure of money, but we must follow European nations in this respect, who are now conducting the regular biological examination of drinking water in nearly all large cities.

DISCUSSION.

THE PRESIDENT. This is a subject, gentlemen, in which we are all interested, and I think I simply voice the feeling of all the members of the Association when I assure Dr. Smith that his effort to day has not fallen on barren ground, and that his paper will be read by a very much larger audience than is present here this afternoon. The subject is now open for discussion. I see a number here who

are interested in this matter directly, and I hope that they will have something to say. I will call on Prof. Sedgwick to add a few words on this subject; it is a matter he has had very much at heart I know for a great many years.

Prof. Sedgwick. If I had had bacteria at heart for a great many years I suppose I should not be here now. Dr. Smith has told us that they are generally in the alimentary canal, which is perhaps the better place to keep them. I was sorry that our president did not get a chance to tell the Association in a few words just who and what Dr. Smith is, because I think when a new expert comes into our neighborhood and becomes, as I trust Dr. Smith may, one of us, we all want to know who he is; and if he will allow me to say a word or two about him, I think perhaps it will interest the Association quite as much as if I said anything on the subject upon which he has spoken.

Dr. Smith, after having graduated at Cornell University, and, if I am right, at the Albany Medical College, went into the employ of the United States government and became the head of the department of pathology, in the Bureau of Animal Industry. That is to say, it became his duty to follow up the diseases that come under the cognizance of the Department of Agriculture. This gave him very unusual opportunities to study the diseases of the lower animals, the diseases of swine, poultry, and so on, in all of which he has done magnificent work, and his papers are rightly regarded as of the very first importance on all these subjects.

Now, when the diphtheria scare, I won't say scare, when the diphtheria *science* I ought rather to call it, began to grow up within the last two or three years, the State Board of Health of Massachusetts saw that not only diphtheria, which was possibly transmitted through the lower animals, but also that many other diseases, such as malaria, possibly even typhoid fever, and some other things of which we have as yet comparatively little knowledge, were likely to become important, and that it was its duty in promoting the health and welfare of the citizens to have the very best knowledge upon all these subjects it was possible to obtain, it undertook to persuade Dr. Smith to leave his important position in Washington and become attached to the Board. And it is with very great pleasure to all workers connected with the Board, and to all citizens of the state who know anything about it, that Dr. Smith has finally con-

sented to come, has become connected also with Harvard College, and is now established in the laboratory belonging to the State Board of Health in the Bussey Institution of Harvard University out at Forest Hills.

Just at the moment, Dr. Smith is, I believe, working mostly upon the diphtheria anti-toxine, because it is highly important to have that in the right hands. But he is also ready, as occasion may demand his services, to take up the study of the origin, transmission, etc., of malaria; in fact he has already begun this investigation; he is ready at any time to devote his attention to an epidemic of cholera if it should come among us; he is ready to take up typhoid fever and find its ways and means among our people. In fact he is an expert employed now by the State Board of Health to look after the more intricate problems of the germ diseases as they may occur in this commonwealth. By virtue of the training and the work which he has had and done, we as citizens, those of us at least who are citizens of Massachusetts, and I think we may say all New Englanders too, (for knowledge and help of this kind radiates all through New England,) may congratulate ourselves that he has come among us.

The paper which he has given seems to me to require no comment. Any one who is familiar with the subject can see that it is written from a most thorough and intimate scientific and practical acquaintance with the subject with which he has had to deal; and I will not take your time by endeavoring to fasten more strongly the points which he has made. We can all heartily agree with them, and it seems to me we ought at this time especially to welcome Dr. Smith as an ally. If any man here having in charge a water supply finds some obscure disease charged by the citizens as coming from that water supply, he will find in Dr. Smith a strong arm working for his defense. I sincerely trust that we shall not be long in asking Dr. Smith to become a member of this Association.

I can also testify on my own part for Dr. Smith's information that he will find in this Association the men who practically oversee and manage the water supplies of New England; a body of men thoroughly practical and ready with every possible accomplishment that skill and engineering can supply. I have often been deeply impressed with the readiness and ability of the superintendents of the water works of New England. They are men also, as I think Dr. Smith will be glad to know, who are entirely ready and willing to

take up, as soon as it is established on any well thought out and well substantiated facts, any plan to prevent the spread of infectious diseases. We want in New England to have the best possible water supplies, and we are getting them little by little. I have always found the members of this Association most ready and eager to support the sanitary authorities in any judicious and right-minded measure. I think the Association should be congratulated on having heard Dr. Smith, and I think Dr. Smith is also to be congratulated on having met the Association.

THE PRESIDENT. I think we all subscribe to what Prof. Sedgwick has said, and that you are to be congratulated on the fact that I did not attempt to do what he has so much better done, and with a so much more intimate acquaintance with the subject. The paper is now open to you, gentlemen, for still further discussion, and I hope if there are any points which are not perfectly clear in Dr. Smith's paper you will ask him questions to bring them out. I would like to hear from Mr. Whipple, who has had charge of the laboratory for the the Boston water works, and if Mr. Whipple says anything on this subject I hope he will give a statement of the number of bacteria ordinarily found in Boston water, which I think is very low, and which Dr. Smith will be gratified to learn.

MR. WHIPPLE. In regard to the bacteriological work which has been done for the Boston water works, I may say that for the past three or four years we have made regularly, once each week, a bacteriological examination of the water in the reservoirs and in the various gate-houses on its way to the city, and the averages of these results by months are as follows:

BACTERIA IN BOSTON WATER.

Number per cubic centimeter.

Average of weekly analyses for four years (1892–1895 inclusive), samples collected from a tap in Park Sq.

Jan.	135	July	73
Feb.	211	Aug.	81
Mar.	102	Sept.	86
Apr.	52	Oct.	55
May	53	Nov.	56
June	86	Dec.	52
Mean	87		

I would also say that for the past two or three years we have been using Dr. Smith's method of the fermentation tube in identifying the bacillus coli communis, and we have found it to be a very successful one.

Dr. Smith. It may be of interest to the members to compare the numbers of bacteria as mentioned by Mr. Whipple with those in the Potomac water used in Washington. In the winter, when the water is very turbid, the numbers rise from 1,000 to 8,000; in the summer, when it is very clear, the numbers fall to 100 or 150, and fluctuate between those two extremes.

The President. I should like to ask Dr. Smith if it has not been found that the crews of some vessels which go from the Potomac to South America, for instance, have been seized with malaria where they have depended upon the local waters, and where they have taken a supply of water with them for the whole voyage they have not had malaria? I have heard that statement made, and it has been brought forward as an argument in favor of the theory that malaria is transmitted in water.

Dr. Smith. I do not recall any such instance. The history of medicine for the last fifty years, however, is full of similar illustrations, but a good many of them don't hold water. (Laughter.)

Prof. Sedgwick. Mr. President, there was one thing brought out by Dr. Smith which I think we ought always to keep in mind, and that is with regard to the explanation to give to people when they say: "Why, I have drunk this water for the last ten years, and you see how much I weigh," and when they add to that: "and not only so, but my father drank it, and lived to be ninety-nine and my grandfather reached a fine old age," and so on. Now, the answer I always give to these people, and it is one which I think very useful, is that "that is all right," and then I say: "Look here, did you ever see a Grand Army procession?" They say: "Yes." "Well," I say, "they look pretty healthy." "Yes, they are remarkably healthy—about pension time especially." "Well, then, war isn't a bad thing, judging by these people. I saw them march here in Boston two or three years ago, and as they went down the street they were a magnificent set of men, splendid; and as I looked at them I thought war isn't such a very bad thing after all." Now, the point is the same in both cases. These are the survivors. We don't see those who

are lying in the graveyards hereabouts, or at Arlington or elsewhere; and because you and I and a half dozen others have been tough enough, and our ancestors, perhaps, also have been tough enough to withstand all these things, it doesn't follow that a lot of other people haven't died of them. So it is well to remember the Grand Army when we are thinking of these things, and not to judge of war by the survivors. If you are going to judge of the effects of war, you must judge by the numbers killed, and they are not generally on hand to be counted.

If I found anything at all to, I won't say criticise, but to wonder at a little in Dr. Smith's paper, it would be his feeling that all sewage contains the germs of typhoid. Perhaps I am stating it too strongly, but that was the idea, at any rate, that if sewage runs into a stream, say for one day or for one week, from a city, it must contain typhoid. It seems to me that there is a little danger in that argument, that it might prove almost too much, because there are times when cities have drunk sewage-polluted water for a considerable time without any appreciable amount of typhoid. And I don't think I can go quite as far as Dr. Smith does in that matter. There were times under the old regime, before their water works were improved, when Lowell and Lawrence used to drink very straight sewage-polluted water, and yet there were such times when they had very little typhoid fever. And those times curiously enough, were generally in midsummer, In fact it was the case all along that river that we got the worst typhoid after a freshet, when the amount of sewage as such in the water was relatively small, the amount of rain water being relatively large. So it seems to me if we don't look out, Dr. Smith's argument will prove a little too much.

But it seems to me that in the main Dr. Smith's point is perfectly sound. We want to avoid the appearance of evil, of course, here as in other things. We don't want sewage polluted water, and it is a fact, and a fact of which I think this Association has great reason to be proud, that in New England the water works are being put into most excellent shape. Lowell and Lawrence were, perhaps, the worst sinners, but they are both of them on the road towards good water supplies and it is a matter for very great congratulation.

With regard to the Boston water, the numbers of bacteria we find at the tap at the Institute are often a little higher than those Mr. Whipple gives, but we are not frightened by moderate

numbers. I was very glad indeed to hear Dr. Smith take the ground he did in regard to the numerical estimate. About all that means, of course, is the relative cleanness of the water. But even that is a great deal, and it seems to me his ideas on that are exceedingly sound. All these latter points for the determination of the species are invaluable to the biologist. We can hardly expect that the ordinary New England water works superintendent will follow that very closely or care very much about it. He looks to the bacteriologist for results, and he will apply them when he needs to do so.

I was particularly grateful to hear Dr. Smith say so much about personal infection. I was laughed at a good deal when I brought up some reports to the State Board of Health proving that certain epidemics of typhoid were due to secondary infection, as I called it, that is, by actual filth conveyed from person to person. Having found that the wells were not bad and the water supply was good, I finally hunted it down and found it had gone in a sneaking, round-about way from person to person. I felt it almost a duty to say it was water or milk, but the facts were the other way; and it is true undoubtedly, that some epidemics have been charged to water and wells when the wells have'nt had anything whatever to do with them. And there again it seems to me Dr. Smith hit the nail on the head. There are not many men in this country, let me tell you, who are ready to take the ground that Dr. Smith has taken, and which I believe firmly to be true, that the trouble with wells comes in as a rule from the top and not from the ground. If at Lawrence five feet of sand can remove all the disease germs, how in the world are they going to get through, except in the rarest cases, into the bottoms of wells from adjoining sources of pollution? I ventured to say this at Chicago before the American Public Health Association, and some of the wiseacres there who have been talking about wells and the dangers from wells for years, laughed me to scorn and were really quite angry about it. It is an old idea, you know, that if you have a cesspool up here and a well a little lower down, you can easily draw on a blackboard a figure showing how the filth from a cesspool finds its way down to the bottom of a well perhaps 50 or 20 feet away. Now perhaps it does; in some cases I believe it does, but it is a significant fact that all the time we have been studying typhoid here in Massachusetts for five years, and studying it hard, we have

never found more than one or two cases in which we even strongly suspected a well. The fact is, as Dr. Smith says, and I believe it implicitly, that whenever you get an infected well, the infection comes in at the top. You may get of course the seepage from a cesspool or anything of that kind, but in nearly every case it is well filtered and well purified on the way. When you get infection in a well I believe you get it in at the top. I have believed it for several years and have been criticised for believing it, and I welcome Dr. Smith's statement therefore as a most happy substantiation of those ideas of my own. We must look at facts rather than merely at books, and we must not generalize from one case. It seems to me Dr. Smith has done us a very great service in putting the matter as clearly as he has this afternoon.

MR. NOYES. It has occurred to me that possibly Prof. Sedgwick has made his last statement somewhat more broadly than the facts would warrant—that is, when applied to all wells under all conditions. I suppose he means a well that is sunk in a drift material, or a material through which water has to pass very slowly, and where the material acts as a filter. There are other cases where water reaches the well from distant points through fissures in the rocks or by other channels to which this would not apply, and it seems to me it is proper to put that on record as qualifying his statement rather than to have it misjudged by persons casually reading the report of this meeting.

PROF. SEDGWICK. I am much obliged to Mr. Noyes. Of course that is perfectly true, and that is exactly what I meant. Where there is an open connection from cesspool to well it is like going in from the top, of course.

MR. THOMAS. As bearing out what Prof. Sedgwick said in regard to Lowell, the agent of the Lowell Board of Health informed me the other day that the amount of typhoid fever in Lowell would be about 50 per cent. less during the year 1895 than it was in previous years. He also informed me that during the month of August there was not a single case of typhoid fever reported in Lowell.

DR. SMITH. I would like to say a few words in regard to the suggestion made by Prof. Sedgwick. I think it is perfectly true that my statement was a little overdrawn. What I intended to say was that we should act as if all sewage-polluted water contained typhoid germs. We should not let any sewage-polluted water go into the

intestines of people without doing something to it. Furthermore, in large communities there are always some cases of typhoid, and hence always a few typhoid bacilli in the sewage from such communities. We have still a great deal to learn concerning the passage of the typhoid fever bacilli into the intestines and the subsequent outbreak of the disease. I trust that the method which has just been suggested in Germany will help us to diagnose mild cases of typhoid, and I hope it will also enable us to demonstrate the presence of typhoid fever bacilli in sewage-polluted water. Another fact to be taken into consideration is this, that typhoid is not a very mortal disease. Only about 12 per cent. of the people who have typhoid die. How many more may swallow the germs without contracting the disease at all, we do not know, but I trust that we shall some time.

In regard to direct infection I would say that Brieger has described in his article several cases of nurses in whose stools the germs were found. This certainly points to direct infection from patient to nurse.

Mr. Richards. We have heard very much about sewage contamination, and I now would like to ask Dr. Smith if it is proven that water is contaminated in any other way; for instance, whether swamp water communicates disease, or if there is any disease carried in water but that which is conveyed through sewage contamination.

Dr. Smith. I think what I said about malaria would cover that question pretty thoroughly, because malaria has generally been considered as being transmitted by swamp water and not by sewage-polluted water. On this subject we know nothing positive. The known diseases which I have described, except possibly malaria, can come in no other way excepting from another person indirectly or directly, and consequently swamp water must be first infected by the germs of the specific disease. But there may possibly be forms of dysentery or of diarrhœa which are due to water bacteria and such bacteria as live only in swamps.

Mr. Richards. That is not proven?

Dr. Smith. I know nothing definite about that subject, and I think there is nothing on record.

The President. I should like to say it is not only from wells we are likely to get direct sewage contamination in our water supplies, for in the course of my own examinations I have seen sewage coming

directly into water supplied to cities and towns in tunnels and in other places, through fissures in the rocks, as Mr. Noyes has suggested, in places that are almost unknown to the authorities. This is a subject I hope to have something to say about at some future time more in detail. I think it is a matter which has never been very much discussed, but I believe it to be worthy of very careful consideration. We should build our aqueducts and tunnels which are constructed to carry pure water to a city, in such a manner that the soil water cannot enter them, at any rate where there is danger of sewage contamination.

MR. COGGESHALL. It is a popular belief, (I don't know that there are any facts to substantiate the truth of it,) that years ago malaria was an unknown disease in the New England states; that at first it made its appearance in the western part, and then spread rapidly in the Connecticut valley, and finally traveled on until it appeared in Providence and many of the eastern cities. Now, has any theory ever been presented in regard to that which would explain it?

DR. SMITH. I regret to say that all that is known of malaria now is that it is due to certain organisms living in the blood; anything beyond this is all conjecture, but we hope to take up this question and do as much as we can towards solving it, if that is ever possible. It is a very obscure question at the best owing to the nature of the organisms which produce the disease.

PROF. SEDGWICK. Has the malaria germ ever been found outside the body?

DR. SMITH. Some Italian observers have described it, but I think the statement is not at all reliable.

MR. COGGESHALL. Can you tell me whether it is as apt to occur in a salt marsh as in a fresh water swamp?

DR. SMITH. I am unable to answer that question directly. I believe the most dangerous marshes are those that have brackish water, where fresh water mingles with the salt water and the salt water with the fresh water. I think that is a statement current in the books.

MR. CHASE. The last annual report of the State Board of Health of North Carolina contains a very elaborate paper by Dr. Lewis, secretary of the board, on the relation of drinking water to malaria. He has made an extensive investigation and considers he has demonstrated the connection of malaria with drinking water, and he

bases it largely upon the fact that in the eastern portion of the state, where heretofore they have been dependent upon shallow wells or small streams, but where they have now introduced the use of deep artesian wells, malaria has disappeared. And investigations of my own in certain localities have given me that idea. At the same time I have been confronted with the fact that a party of young men who went to a village in the eastern portion of the state, and who were so very much afraid of having malaria that they would not trust the local waters at all, or even rain water, but confined themselves to apollinaris, had malaria worse than any other people living in the locality.

The President. I understood Dr. Smith to state that there was no theory to account for the prevalence of typhoid fever in September. But following out your statement as to the pathogenic germs in water, why is it not possible that the low flow of the streams in September concentrates the number of germs to such an extent that that might account for the increase in the disease? You know that the streams are very much lower at that time of the year than at any other time.

Dr. Smith. That is true, but the evidence we have is complicated by the great movement of people between the city and country at that season of the year. In the country, wells are largely in use.

The President. Might not the amount of water in the wells have been very much smaller at that time, and the dilution very much less?

Dr. Smith. Undoubtedly concentration plays a part in it, but the further the ground water is below the surface the less it would seem likely to become polluted.

A Member. I would like to ask one question. You spoke of a boy who fell into the river and the next day was taken down with cholera. Now, I have heard the question asked a good many times as to whether a single glass of milk or a single glass of water containing typhoid fever germs was sufficient to produce the disease. In connection with this fact of the water being filtered in a well, and therefore the number of organisms being small, I would like to ask Dr. Smith if he considers it is necessary to drink typhoid contaminated water on a number of different occasions, or whether a single dose would probably be sufficient to produce the disease.

Dr. Smith. That is a very difficult question to answer. Experimentally we know that the smaller the number of germs we inject under the skin of a rabbit or guinea pig, the less likely it is to cause the disease in the animal. With some bacteria we can reduce it to a point where no disease will appear, and the system will get the better of the germs. As we increase the number, the more likely we are to produce the disease, and at a certain point it is always produced. One germ which is taken in a glass of water may be destroyed, another in the next glass may be destroyed, and in the third glass there may be five or six, and these may begin to multiply and start the disease. Of course it is possible that the disease if it appears at all may come from a single germ. It is a very difficult question to settle in any way except by experiment. It should always be borne in mind that the receptivity of the individual varies from time to time.

On motion of Mr. Noyes a vote of thanks was given to Dr. Smith for his valuable and interesting paper.

DESCRIPTION OF SECOND TUBE WELL PLANT AT LOWELL, MASS.

BY

Geo. Bowers, City Engineer, Lowell, Mass.

[Read Feb. 12, 1896.]

On June 14th, 1894, I read a paper before this Association which included a description of our first tube well plant, "The Cook Wells." In August of that year a contract was made by the city of Lowell with the Hydraulic Construction Company of New York, for a plant of tube wells of sufficient capacity to furnish and deliver into the city mains 2,000,000 gallons of water each and every day of twenty-four hours. The contract stated that these wells should be located in the same valley with the Cook wells. and should not deplete or take water from them. To select a location that would fulfill the requirements of this contract was a difficult piece of work, requiring the testing of the ground for a mile and a half up the stream southerly from the Cook plant. To do this thoroughly seventy test wells were put down. The place selected was about one mile south of the Cook plant on the northerly side of River Meadow brook.

The first permanent work done was the construction of what is now known as Section A. January 3rd, 1895, this section contained forty-two 2-inch wells, 45 feet deep, placed on each side of a 12-inch suction main, 25 feet apart and 6 feet from the suction main. The connections were at an angle of forty-five degrees with the main, and the wells made with perforated brass screens. A test of these wells was made from January 10th to 27th, the actual time of test being sixteen days, eleven hours, twenty-three minutes. and

the quantity of water pumped 29,972,597 gallons by meter measurement; during the test the ground water was lowered about ten and one-half feet. All the temporary tests at this plant were made with a fifty horse power engine and an 8-inch centrifugal pump.

Another section (now known as Section B) consisting of seventeen wells was then built and tested by pumping six days, five hours, thirty-four minutes, the quantity pumped being 5,283,599 gallons. During these tests the suction main was near the surface of the ground but was afterwards lowered about five feet.

On account of the large amount of water in the ground (it reaching nearly to the surface), it appeared to be a very difficult piece of work to lower the main, excavate for the pit and build the foundation for the permanent pumps; but by making use of the wells already driven to lower the ground water, this difficulty was, in a large measure, overcome.

A large cast-iron receiver was first set in place, then Section A was pumped while Section B was being lowered, the pit excavated, the permanent pumps set in place and twenty-three more new wells added, making forty wells in Section B. The permanent pumps were now started and the wells of Section B pumped while the suction main of Section A was in its turn lowered. While this was being done 2,300,000 gallons of water were daily pumped into the city mains. On June 6th, the construction of Section C was begun. This, the third section, was laid out at right angles to the other two sections and was finished October 7th, although a portion of this line was in use long before the whole was completed. In building this section a very deep deposit of soil was found, extending for a distance of about three hundred feet and varying from six to thirty-five feet in depth. No wells were driven in this place and the suction main was supported by piles. Every twelve-foot length of pipe was supported by four piles driven through the soil into the sand or gravel below; this work necessitated more time than would otherwise have been required for building this section. The plant now consists of 120 wells connected by 1,519 feet of 12-inch suction pipe. The pumping is done by two Worthington pumps each capable of pumping 3,000,000 gallons of water daily.

From April 5th, 1895, to February 1st, 1896, 921,063,299 gallons of water were pumped and measured by a Venturi meter. The amount pumped each month was as follows:

Pumpage at the Hydraulic Construction Company's Wells.

1895.

Month.	Gallons.	Remarks.
April........	71,516,074	Commenced pumping April 5, 1895.
May..............	76,529,295	
June...........	70,107,764	
July	92,862,888	
August...........	95,203,073	
September.......	88,455,627	
October....... . .	102,212,358	
November.........	106,443,065	
December.... ..	110,746,609	
January, 1896.....	106,986,546	
Total...........	921,063,299	

Average quantity pumped per day, 3,049,878 gallons.

This plant has never been pumped to its limit, the contract requiring not less than two, nor more than three million gallons to be pumped each and every day. The contractor has pumped, except during a break in the suction main in September, just a little over three million gallons per day.

During the great rainfall of November the valley became flooded and soon greatly increased the amount of water in the wells. Iron and lime were found in the water from Section A at this time which necessitated the closing of those wells; this, however, is only a temporary trouble.

I wish to call your attention particularly to this method of pumping the water when construction is being carried on in wet places. If the right kind of well is used and properly sunk, so as to intercept the water, the pressure of the ground water will be taken care of. If the excavation is in sand or gravel this will be all that is needed; but if there should be a stratum of clay or impervious material which prevents the water getting to the wells, this surface water would have to be pumped also. I recently used an ejector for the surface water with very good results. By this method the place excavated is left in an excellent condition for building.

DISCUSSION.

In reply to a question from the President, Mr. Bowers stated that a 20-inch Venturi meter was used for measuring water. It was being watched very carefully, and is believed to be recording the quantity of water accurately, probably within two per cent. It is placed back of the pumps so that any air drawn from the wells has been removed from the water before it reaches the meter and no disturbance can be produced in this way. The quantities given were determined with this meter. The hardness of the water at the present time is about 4.0 degrees; it has been as high as 7.0 and 8.0.

In reply to a question from Mr. Holden he stated that the wells were from 45 to 50 feet deep, and that although there was more water in the wells two or three weeks after a rain than at other times, he did not think that any brook water found its way into the wells without being adequately purified.

Mr. Rice stated that he had been much interested in what Mr. Bowers had said, and had followed his investigations with a good deal of interest, because he had been an assistant of Mr. Davis in 1870 when the original works were built. He stated that at that time Mr. Davis thought that the best system would be to have settling basins along the Merrimac river. The filter gallery was not an idea of Mr. Davis, who built it only on the explicit order of the Water Board or city Council; and he wanted to call attention to the method of filtration in use at Lawrence as the proper system for supplying such a city, and as better than the driven wells. Mr. Rice further stated that with the tendency towards hardness and iron there must be an end to using the driven well water in Lowell, and he understood that the city hall had cut off its water supply and was now using water supplied by the Merrimac Corporation.

Mr. Bowers in reply stated that the man who takes care of some of the boilers in the city hall did not take proper care of them, and as a result had had some trouble and had recently changed from city water to the river water, but in other cases where boilers were properly taken care of no trouble had been experienced with the driven well water. He did not consider the hardness of the well water as excessive, and it was apparently not increasing, for the analysis had not changed during the past year.

HANDLING FIRES WHILE CHANGING DISTRIBUTION MAINS UPON IMPORTANT STREETS.

BY

GEO. F. CHACE, Superintendent Taunton Water Works.

[Read Feb. 12th, 1896.]

Taunton has that method of water supply held in such low esteem by New England engineers, namely, the Holly System of Direct Pumping.

When the works were first built, in 1876, there was only one principal force main from the pumping station to the city, 20 inches in diameter, 1.3 miles long, and feeding a 16-inch main, 1,690 feet long, which runs through Main street.

In 1880, a second force main was laid from the pumping station over another route. This line consisted of 1,300 feet of 12-inch, and 1,900 feet of 10-inch pipe which joined an 8-inch pipe, 1,451 feet long, which was connected with the 16-inch pipe running through Main street.

In 1894, the above 8 and 10-inch mains were replaced by 20-inch. During the past year about 5½ miles of 12, 10, 8, 6, and 4-inch mains have been replaced by 20, 16, 12, and 8-inch pipes. This work involved changes through some of the principal business thoroughfares and included the completion of a second 20-inch system from the pumping station, giving the city now a duplicate 20-inch supply.

As Taunton now has a population, according to the census of 1895, of 27,093 and uses only 43 gallons per inhabitant per day, either one of these mains is sufficient to supply the city for a long time to come.

The work of replacement this year began in April and continued without interruption until October and was not entirely finished until the middle of November.

The changes were carried on simultaneously in two parts of the city, in one by a contractor, and in the other by the water department.

During this period the traffic of the streets was not seriously interrupted, the domestic supply did not fail upon any street, and an adequate fire pressure was not wanting at any one of 31 fires.

Some of you will remember that a few years ago a large part of the business portion of an important town in Worcester county was destroyed by fire, because the latter occurred at a time when the supply from the reservoir was interrupted for repairs upon the force main, which was the sole reliance for connecting the reservoir with the distribution mains of the town.

The same kind of disaster would undoubtedly have occurred in Taunton last spring if the city had not possessed more than one line from the pumping station.

As I have been asked to give a short experience paper, the experience of the Taunton Water Department in handling the most dangerous fire of the past season, while distribution changes were going on, may be of interest, and one example may serve for all.

On May 31, at 2.49 p. m., there was an alarm for a fire in the rear of Union Block. This is a three-story brick building on the corner of Main and Weir streets in the business heart of the city. The fire started among some old rags which had been used in polishing furniture and which were lying in a small wooden annex belonging to a furniture and crockery store in the brick block. This block in the rear was four stories high, with an attic, having a window in the gable, facing the rear alley way. The flames very quickly mounted into the upper story and attic, as well as into the store room on the lower floor of the brick structure.

In the rear of Union Block is a dangerous fire trap of old wooden stables, dwellings, planing mills, saw mills, and lumber yards.

A few minutes before the fire alarm sounded I had started, in company with a building contractor, who had been doing some work for us, to visit our Lakeville pumping station. I told him I must wait and see what the fire was, before I thought it would be prudent to leave town.

There is a private alley leading from Main street to the rear of Union Block, and another leading from Weir street to the same point. Opposite the alley way on Weir street is a 4-way Chapman hydrant. On Main street, about 50 feet from the head of the alley leading from this street, is another 4-way Chapman hydrant. There is a 16-inch pipe on Main street and an 8-inch on Weir street. Within a few feet of the burning building was a 2-way hydrant at the end of about 200 feet of 4-inch pipe, leading out of the 8-inch on Weir street.

When I reached the scene, which was within ten minutes of the alarm, the fire department had four hose lines laid from the Main street 4-way, three lines from the 4-way on Weir street, and one from the small hydrant in the rear. Some of these lines had already begun to throw streams. In a few minutes they were all playing.

But for a while the fire appeared to be having its own way. It had run up into the attic where there was no chance to reach it in that quarter except through the gable window already noticed. The fire department had a Hayes' truck aerial ladder, to use as a water tower; but, being cramped for room, the firemen had some difficulty in getting this apparatus into an effective position. Meantime, the flames began to break through the roof. It was a hot day, the thermometer reaching 88° F. at noon, and the domestic consumption was large. Fearing the number of hose streams would soon have to be doubled, I hurried to the office telephone and ordered the second engine started, as a precaution. I was gone from the scene of the fire about ten or twelve minutes. On my return I found the Hayes' truck and ladder was in position and a powerful stream from a nozzle on a level with the gable window was playing directly into the heart of the attic fire, and the threatened conflagration appeared to be under control.

At 4.10 p. m. the fire was out and the recall sounded. In one hour and twenty-one minutes a very threatening fire, in the business center, in the midst of a perfect tinder-box of combustible material, had been completely squelched. The blaze did not get through the door of the store room into the main store filled with valuable crockery. A lounge in the attic for repairs, although somewhat drenched, was not even scorched. Some pictures of footlight favorites on the attic walls were still hanging in all their tawdry glory.

The amount of risk and loss will be understood from the following

figures furnished by courtesy of the chief engineer of the fire department.

Value of building	$6,500
Insurance on building	4,000
Loss on building	1,025
Insurance paid	725
Value of contents of building	3,200
Insurance	2,750
Loss	1,750
Insurance paid	1,750
Loss to the insurance companies on $9,700 was	$2,475
Loss to the owners	300

The latter was on the wooden structure which was uninsured.

A failure in the pressure at the critical period of this fire would have been disastrous. The surroundings were very combustible and there were other valuable stocks in Union Block in addition to the property contained in the furniture store.

The men of the water department had strict orders to keep everything heavily braced where there was a chance to blow out temporary plugs on unfinished work, and these orders were faithfully obeyed.

Although one force main from the pumping station was out of commission, because of the change in progress from 12-inch to 20-inch pipe, the other 20-inch main kept up the supply.

If more streams had been needed, there were four additional 4-way hydrants within 500 feet of the spot where the fire started.

DISCUSSION.

In reply to questions from the President and others Mr. Chace stated that there was no reservoir in Taunton, but that a pressure of 100 pounds was maintained at the engines; and while he did not know the exact pressure on the hydrants, there were usually 90 pounds shown on the gauge at the office, and that with 15 fire streams in use at once there had been 64 or 65 pounds pressure, and with 12 streams 70 pounds had been noted. He also stated that only one engine was kept in reserve but that was ready to start at any time and that a full supply could be obtained within one or two minutes.

In reply to a question from Mr. Haskell he stated that he should be glad to have a standpipe, but that the city was not altogether dependent upon the engines, for the water is received by gravity under a pressure of 28 pounds.

THE FRICTION IN SEVERAL PUMPING MAINS.

BY

FREEMAN C. COFFIN, C. E., Boston, Mass.

[Read Feb. 12, 1896.]

I have recently had opportunities to experiment upon several pumping mains, and in a practical manner to determine the friction caused by the flow of water at different velocities, and to compare the results with the formulæ in use.

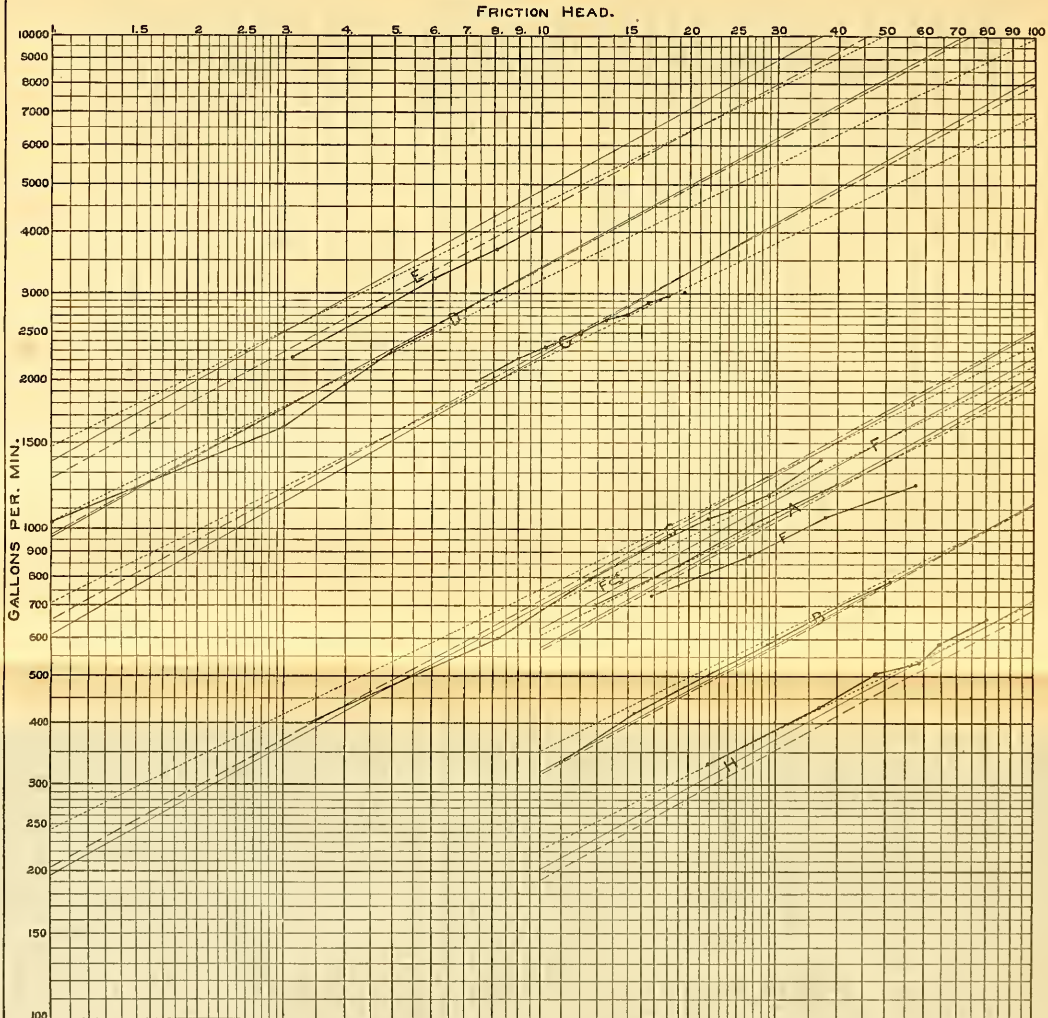
The velocity or quantity of water was obtained from the revolutions of the pump, with a proper allowance for slip in each case. The friction head was measured by the difference of the static and dynamic head as shown on the pressure gauges connected with the main. I believe that there was no error from the readings of the pressure gauges to exceed one foot, and in most cases the errors were much less, as the gauges were graduated to a large scale. It was my endeavor to have all such errors, if any, on the safe side, or on that of increased friction. The gauges were so nearly accurate that there would be no appreciable error in the range covering the increase of pressure due to friction.

The static head was observed before the pumps were started, and, in cases where the water was pumped into a standpipe, account was taken of the rise of water or increase in static head.

The observations of the pumps were carefully made, both as to revolutions per minute and length of stroke, and although the extreme accuracy of carefully made hydraulic experiments was not possible, I believe that substantial accuracy sufficient for practical purposes was obtained. The fact that the mains were long, tended to reduce the proportional error due to errors of observation.

IPSWICH MAIN.

This was a compound main consisting of 9,060 feet of 12-inch pipe with no bends except those of long radius, no side outlets and perhaps half a dozen house services; 1,000 feet of 12-inch pipe continuing from the first one, but with an 8-inch side outlet at its junction with the first portion and a 6-inch side outlet at about one-half of its length. These pipes passed into a system in



Friction in Pumping Mains.

February 1896.

Freeman C. Coffin
Boston Mass.

Diagram: No. 1

Actual Friction ————
Smith-Chezy Formula ————
W. E. Foss " – – – – –
Darcy " ....

A { Ipswich Main. 9060 ft. 12 in. Pipe. 1000 " " " " 1150 " 14 " "

B { Walpole Main. 6950 ft. 12 in. Pipe. 8900 " 10 " "

C { Attleboro Main. 6400 ft. 16 in. Pipe. 10750 " 14 " " 375 " 12 " "

D { Taunton 30 in. Conduit. 38700 ft. 90 in. Pipe.

E { Taunton 24 in. Main. 6000 ft. 24 in. Pipe. 50 " 18 " "

F { Brookline Main. 9070 ft. 14 in. Pipe. 16250 " 16 " "

G { Hoboken Main. 10000 ft. 20 in Pipe.

H { South Walpole Main. 8874 ft. 8 in. Pipe. 1735 " 10 " " 197 " 12 " "

such a manner that I estimate that one-half the flow passes through the 1,000 feet of 12-inch pipe; but it must be admitted that there is an element of uncertainty in this part of the line. However, it would make but little difference in the total result whether one-fourth, one-half or three-fourths of the water passes through this short length, as the total computed friction through it is very small as shown by the seventh column in Table A.

The remainder of the line to the reservoir was 1,150 feet of 14-inch pipe without branch or service. The total flow from the pump with the exception of the ordinary consumption, passes through this line into the reservoir. The total daily consumption was 40,000 gallons; assuming that seventy-five per cent. of this was used in the twelve day hours, then the average day hour consumption was forty-two gallons per minute, which was the amount deducted from the total to get the amount flowing through the 14-inch pipe. There was one right-angled bend made by a globe special at the junction of the 12 and 14-inch lines, as well as several gates and globe special hydrant branches on the lines and also two check valves.

In Table A are given the results of these experiments and a comparison of the actual friction with that computed by means of the Chezy formula $V = C\,(rs)^{\frac{1}{2}}$ or $s\ \frac{v^2}{c^2\,r}$ using for the coefficient c the values given by Hamilton Smith, Jr., as estimated from his diagram for the different sizes of pipes as closely as possible. These values are given on diagram No. 2.

WALPOLE MAIN.

This is a compound main consisting of 6,950 feet of 12-inch pipe and 8,900 feet of 10-inch pipe. At the time of the test there was no consumption and no side mains open to complicate matters. There were four right angle bends made with globe specials and six long bends, many hydrants and other branches and gates upon the line. The water was pumped into a stand-pipe. The static pressure was observed before the pump was started and after it was stopped at the end of the experiments. The static head for each experiment was estimated in proportion to the amount of water pumped into the stand-pipe at the time the experiment was made. The total rise in the stand-pipe was 4½ feet. The slip was taken as 2.5 per cent. The results of these experiments are given in Table B.

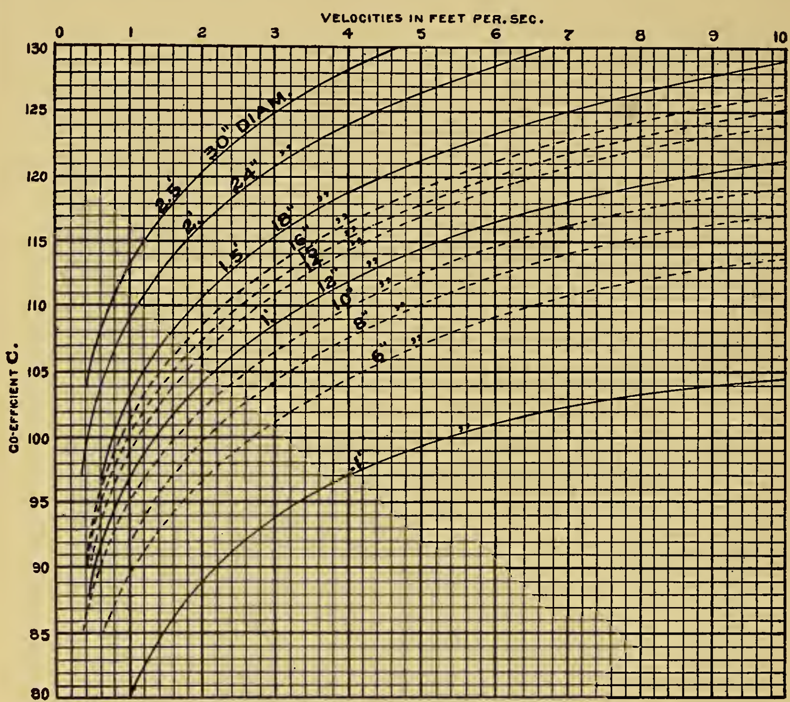


DIAGRAM SHOWING VALUES OF C.

FOR CLEAN STRAIGHT PIPES—$V = C\,(rs)^{1/2}$

FULL LINES FOR SIZES .1, 1., 1.5, 2. AND 2.5 FEET IN DIAMETER.

TAKEN FROM HAMILTON SMITH'S HYDRAULICS.

DOTTED LINES FOR 6, 8, 10, 14, 15 AND 16 INCH PIPE ARE INTERPOLATED.

No. 2.

ATTLEBORO MAIN.

This is also a compound main consisting of 6,400 feet of 16-inch, 10,750 feet of 14-inch and 375 feet of 12-inch pipe. The 16-inch pipe which was nearest the pump was entirely free from open side outlets, as was also the 14-inch. The latter, however, supplied at its farthest end, that is the end nearest the stand-pipe, about 250 people; their draft during the hours of the observation would be ten or eleven gallons per minute, but being so near the end of the 14-inch pipe would not affect the results appreciably. The 12-inch pipe carried all the water pumped from the 14-inch pipe to the stand-pipe, except that used by the town, which is estimated at 400 gallons per minute, on the assumption that seventy-five per cent. of the consumption is between 6 a. m. and 6 p. m., and this amount was deducted in computing the friction in the 12-inch pipe.

The stand-pipe was provided with a gauge recording by electricity in the pumping station. The static head was read from this simultaneously with the dynamic head from the pressure gauge on the main. The slip was estimated at two per cent. There were three right angle bends and numerous branches and gates on the line. The results of these experiments are shown in Table C.

TAUNTON 30–INCH MAIN.

This is a simple main of 36,700 feet of 30-inch pipe. It is used as a suction or supply main for the pump which takes the water under a static head of sixty-six feet. These experiments were very satisfactory as far as they went, but the range of velocities was very low, namely from .47 to 1.15 feet per second, the velocity being limited by the safe speed of the pump. The slip of the pumps was estimated at five per cent. The results of these experiments are given in Table D.

TAUNTON 24–INCH MAIN.

This is a compound main composed of 6,000 feet of 24-inch pipe and 50 feet of 18-inch pipe. There are no branches or services upon it. The actual friction in this main exceeded the computed friction by a large percentage as shown in Table E.

SOUTH WALPOLE MAIN.

This was a compound main, consisting of 8,874 feet of 8-inch; 1,735 feet of 10-inch, and 197 feet of 12-inch pipe. The tests were made under practically the same conditions as those upon the Wal-

pole main. There was no consumption and complications of side mains. The water was all pumped directly into the stand pipe. The pipe was laid in 1895. The results are given in Table H.

I was surprised to find that the friction in the Ipswich line (the first one experimented upon) was less than the computed friction for clean, straight pipes. I expected that the gates and branches and two check-valves upon the line would cause considerable loss of head and make the actual friction head above that of the straight pipes as computed by the formula named. The experiments on the Walpole pipe show about the same results and seem to confirm the first.

The older pipe at Attleboro and the Taunton 30-inch line show slightly different results especially in the higher velocities, where the actual friction head is greater than the computed head, and the friction in the Taunton 24-inch line was still more in excess of the computed friction.

It may be that the increased frictions in the Attleboro and in Taunton 30-inch line are due to tuberculation or deterioration of the inner surfaces of the pipes, but this will not probably account for the greater increase in the 24-inch line, and I do not know of any condition that should cause this increase over the 30-inch or the Attleboro line.

The years in which the pipe lines were laid were as follows: Walpole, 1895; Ipswich, 1894; Taunton 24-inch main, 1893; Taunton 30-inch line, 1892, and Attleboro, 1892.

This result of greater friction in the older lines is interesting on account of the significance of the condition of the inner surface of the pipe lines and its influence upon their discharge, especially at this time, when so much interest has been aroused on the subject of the character of the inner surfaces of pipes by the recent developments in regard to the delivery of the riveted steel pipe line of the East Jersey Water Company. It is well known that the roughness of the pipe is an important element, but the degree to which it affects the delivery has not been determined, and it may be that enough consideration has not generally been given to it in designing pipe lines and systems.

Mr. Desmond FitzGerald, in a paper recently read before the American Society of Civil Engineers, shows that in a 48-inch coated cast iron pipe, the removal of the tuberculation of 18 years' growth,

caused an increase of 30 per cent. in the discharge of the pipe, which is equivalent to a reduction of about 23 per cent. in the discharge of clean pipes caused by that degree of tuberculation, or an increase of the frictional head of about 69 per cent.

This conclusively shows that the effect of tuberculation is no slight matter, and although it is not possible at present to accurately state the effect produced by any age or condition of pipe, the fact should be emphasized that it is necessary to allow a wide margin for the increase of friction, or in other words, the decrease in delivery, unless it is intended to clean the pipes, or lay future supplementary lines.

I consider that the results of the experiments described in this paper, indicate that it is safe, in the sizes experimented upon, to use the formula and coefficients mentioned for new pipe lines of coated cast iron, that they also indicate a reduction of the capacity of a pipe line with age, and that this reduction commences in a slight degree in a very few years.

GRAPHIC COMPARISON OF RESULTS.

Diagram No. 1 shows the results of these experiments plotted on Logarithmic cross section paper, and also the theoretical results in clean, straight pipes. The results of three different formulæ are shown in each case by as many different kinds of lines. The author is indebted to Mr. John R. Freeman for the 10-inch base Logarithmic paper upon which the diagram is made.

The actual results are shown by a heavy, full line. Those obtained by the Chezy formula with Smith's coefficient are shown by a light, full line. Those by a formula proposed by W. E. Foss by a light, broken line. This formula which is most convenient. It was proposed and its derivation described by Mr. W. E. Foss in a paper read before the Boston Society of Civil Engineers in 1894, and published in the *Journal of Associated Engineering Societies*, of June, 1894. The results of this formula nearly coincide with those of the Smith–Chezy formula, and it deserves especial mention on account of its extreme simplicity. According to Mr. Foss' nomenclature: $I = C^1 Q^{\frac{11}{6}}$ when $I =$ friction head per foot, $Q =$ discharge in cubic feet per second, and $C^1 =$ a coefficient, a table of which he gives for different diameters. He also gives a table of $\frac{11}{6}$ powers.

The third formula is that of Darcy for clean, straight pipes. This

is represented by a light dotted line. The results of these three formulæ for these sizes of pipes and for ordinary velocities do not differ materially.

Besides the experiments described above, the results of a series of observations by Mr. F. F. Forbes upon a compound pipe in Brookline, consisting of 9,070 feet of 14-inch pipe and 16,250 feet of 16-inch pipe are plotted. A description of these experiments was read before this Association by Mr. Forbes in 1892. The pipe had been laid 18 years, and the actual friction was 25 per cent. greater than that computed by Smith's coefficients at the lowest velocity and 70 per cent. greater at the highest.

The results of a series of experiments on a 20-inch pipe line used as a pumping main for the city of Hoboken, and described by Mr. Chas. B. Brush in the *Transactions of the American Society of Civil Engineers* in 1888 are also plotted. This was a simple main 75,000 feet long. It had been laid five years. The proportional results in 10,000 feet instead of the total length are plotted, so that the curve would not interfere with those of the other experiments on the sheet. The friction in this case does not exceed the computed friction, except in the highest velocities.

It will be seen that in all of the experiments, with the possible exception of the 30-inch Taunton pipe, the actual friction increases faster with higher velocities than the computed friction, either by the Smith or the Foss formula, which are both practically formulæ of the $\frac{11}{6}$ or 1.83 power. The actual friction curve is nearer in direction if not in amount to the Darcy formula which is one of the second power. The Brookline curve is greater still, or one of the 2.35 power.

It is probable that greater roughness tends to even higher values of the exponent.

I believe this increase in the exponent in the new pipes of Ipswich and Walpole (which while it was evident, was not so marked as in the older lines) was caused by the presence of gates and specials in the line, and that if the velocities had been carried higher the increase would have been still greater.

I wish to acknowledge my obligations to Mr. Geo. F. Chace of Taunton and to Mr. William J. Luther of Attleboro for their courtesy in extending to me the opportunities to experiment on the lines under their care, and also for their kind assistance.

TABLE A.—Ipswich Main.

No. of Test.	9,060 Ft. 12" Pipe. Gallons per Minute.	Velocity.	Computed Friction.	1,000 Ft. 12" Pipe. Gallons per Minute.	Velocity.	Computed Friction.	1,150 Ft. 14" Pipe. Gallons per Minute.	Velocity.	Computed Friction.	Total Computed Friction.	Actual Friction.	Per Cent. of Computed to Actual.
1	706	2.00	13.25	353	1.00	.41	664	1.38	.71	14.37	12.85	111
2	860	2.44	19.00	430	1.22	.60	818	1.70	1.05	20.65	19.55	100.5
3	1,020	2.90	26.00	510	1.45	.81	978	2.04	1.45	28.26	27.1	104
4	1,250	3.55	37.40	625	1.77	1.18	1,208	2.52	2.15	40.33	40.3	100

TABLE B.—Walpole Main.

No. of Test.	Gallons per Minute.	6,950 Ft. 12" Pipe. Velocity.	Computed Friction.	8,900 Ft. 10" Pipe. Velocity.	Computed Friction.	Entire Line. Total Computed Friction.	Actual Friction.	Per Cent. of Computed to Actual.
1	334	.95	2.61	1.36	8.17	10.78	10.93	99
2	421	1.20	4.10	1.68	12.45	16.55	15.55	106.5
3	585	1.66	7.30	2.40	22.45	29.75	28.80	103.3
4	704	2.00	10.15	2.88	31.35	41.50	40.3	103
5	792	2.25	12.60	3.24	38.90	51.50	51.80	99.5

TABLE C.—Attleboro Main.

No. of Test.	6,400 Ft. 16" Pipe. Gallons per Minute.	Velocity.	Computed Friction.	10,750 Ft. 14" Pipe. Gallons per Minute.	Velocity.	Computed Friction.	375 Ft. 12" Pipe. Gallons per Minute.	Velocity.	Computed Friction.	Total Computed Friction.	Actual Friction.	Per Cent. of Computed to Actual.
1	402	.64	.85	402	.84	2.80				3.65	3.37	108
2	603	.97	1.76	603	1.25	5.77	203	.57	.06	7.59	8.25	92
3	796	1.27	2.90	796	1.61	9.40	396	1.12	.19	12.49	12.62	99
4	943	1.57	3.96	943	1.96	12.75	543	1.54	.34	17.15	17.25	99.5
5	1,052	1.68	4.80	1,052	2.19	15.40	652	1.85	.47	20.72	21.75	95.5
6	1,083	1.73	5.08	1,083	2.26	16.40	683	1.94	.51	21.99	24.00	91.7
7	1,177	1.88	5.84	1,177	2.45	19.00	777	2.20	.65	25 49	29.00	88
8	1,354	2.17	7.52	1,354	2.82	24.30	945	2.68	.96	32.78	35.50	92.5
9	1,392	2.23	7.85	1,392	2.90	25.50	992	2.84	1.14	34.39	37.00	93

TABLE D.—Taunton 30″ Conduit.

No. of Test.	36,700 Feet 30″ Pipe. Gallons per Minute.	Velocity.	Computed Friction.	Actual Friction.	Per Cent. of Computed to Actual.
1	1,033	.47	1.15	1	115
2	1,610	.73	2.55	3	85.2
3	1,960	.892	3.70	4	92.5
4	2,300	1.045	4.80	5	96
5	2,530	1.15	5.90	6	98.5

TABLE E.—Taunton 24″ Main.

	6,000 Feet 24″ Pipe.			50 Feet 18″ Pipe.					
No. of Test.	Gallons per Minute.	Velocity.	Computed Friction.	Gallons per Minute.	Velocity.	Computed Friction.	Total Computed Friction.	Actual Friction.	Per Cent. of Computed to Actual.
1	4,096	2.91	7	4,096	5.12	.24	7.24	9.87	73.50
2	3,693	2.55	5.80	3,693	4.42	.20	6.00	8.13	73.80
3	3,228	2.29	4.53	3,228	4.04	.15	4.68	6.13	76.50
4	2,785	1.97	3.50	2,785	3.48	.12	3.62	4.75	76.30
5	2,220	1.57	2.30	2,220	2.77	.10	2.40	3.13	77.20

TABLE H.—South Walpole Main.

		8,874′ 8″ Pipe.		1,735′ 10″ Pipe.		197′ 12″ Pipe.				
No. of Test.	Gallons per Minute.	Velocity.	Computed Friction.	Velocity.	Computed Friction.	Velocity.	Computed Friction.	Total Computed Friction.	Actual Friction.	Per Cent. of Computed to Actual.
1	660	4.20	80.00	2.70	5.15	1.87	.26	85.41	80.40	1.06
2	591	3.76	65.90	2.42	4.12	1.69	.21	70.23	65.30	1.07
3	533	3.40	54.50	2.18	3.34	1.55	.17	58.01	58.70	.99
4	506	3.24	49.50	2.07	3.04	1.44	.15	52.69	48.00	1.10
5	432	2.76	37.20	1.77	2.23	1.23	.12	39.55	37.00	1.07
6	331	2.12	23.00	1.36	1.57	.94	.07	24.64	22.00	1.12

DISCUSSION.

Mr. Chace stated that during the past season he had seen some things which had suggested ways in which friction might be increased. He had seen places where chunks of lead had been run in as large as a man's arm, and in one case an 8-inch plug was found in a 10-inch pipe, and he thought that cases like this might account for the increased friction in some of Mr. Coffin's observations.

In answer to a question from Mr. Fuller, he stated that the slip of the pumps was estimated in each case according to his best judgment in view of the pumps used. The pumps were duplex pumps except the Taunton pump, where a fly wheel pump was used, and there the slip of the cylinder was practically nothing.

In answer to an inquiry from the President as to the construction of the East Jersey main, Mr. Sheriff stated that he had read a paper before the Association four years ago, giving a full description of it. There is an outer and inner course of plates. In all cases the length of the plates is 7 feet, and the plates lap about 3 inches when they are one-quarter of an inch thick. The nominal diameter was 48 inches and this was the actual diameter of the outer course of plates which were outside of the inner plates at both ends. The diameter of the inner set of plates was 48 inches, less twice the thickness of the plates at that particular point. For the greater part of the way one-quarter inch plates were used. The result of this arrangement is alternate cylinders of pipe 7 feet long and 47½ inches in diameter, and 6½ feet long and 48 inches in diameter.

Four lengths were put together in the shops and painted with asphalt, and after the pipe was placed in position and the joint made, the latter was carefully coated. The hydraulic grade of the line was 10 feet to the mile, but the line did not by any means follow the hydraulic grade. To have followed the river down would have added very much to the length of the pipe, and in cutting across for the first four miles there was difficulty in getting fall enough, and the pipe line was kept pretty nearly up to the hydraulic grade. Beyond that point the descent was more rapid. Air cocks were provided to prevent the capacity of the pipe being cut off by air pockets.

SOME NOTES ON THE FORMATION OF TUBERCLES IN IRON AND STEEL PENSTOCKS.

BY

R. A. HALE, C. E., Lawrence, Mass.

[Read Feb. 12th, 1896.]

The subject of the coating of the interior surfaces of water pipes and the conditions under which the formation of tubercles occur are of great importance to the water works superintendent and engineer, and a few observations on the condition of penstocks used to convey water for power may prove of interest.

The size of the pipes in general for water power is necessarily much larger than for a system of pipes for distribution about a city, and they differ somewhat in construction and material. The pipes which have come under the immediate observation of the writer are, penstocks located at Lawrence and used in conveying water from the canals to the wheels in the mills.

The lengths of the penstocks vary from 50 to 300 feet—depending on the location of the water wheels in the mill. In general they are made of wrought iron, or steel sheets, about $\frac{3}{8}''$ in thickness, riveted together with $\frac{3}{4}''$ rivets, the sheets being joined together either by a lap joint or butt joint.

In the case of lap joints the penstock is built alternately with joints lapping so as to form an inside sheet and then an outside sheet.

In a second method the upper end of each section is slipped into the lower end of the preceding section, similar to a stove pipe joint or a telescopic joint.

The heads of rivets may be countersunk to decrease the roughness. In the butt joints the sheets are butted together and a ring 4″ to 6″ wide riveted about the outside of the sheets, and with the rivet heads countersunk on the inside a perfectly smooth surface can

be obtained, similar to the surface in a cast iron pipe. In connection with measurement of water used by the mills it has been necessary to make inspection of these penstocks and the condition is usually noted.

The coating which is in general applied to the surface is a good quality of asphalt, applied hot with a brush, when the surface of the iron is bright and before rust sets in. Three coats are usually required in specification. A mixture of red lead is sometimes used; and coal tar dissolved and applied hot has been tried.

It is impossible to give a detailed account of the conditions of the various penstocks when first put in with their coatings, but, in general, the condition is known.

The Merrimac river water rapidly oxydizes iron and steel if without any protection, as tools that have been immersed will testify. The mainspring of a watch dropped in one of the flumes while observations were being made was in a deplorable condition before it could be rescued a day or two after.

Without any special divisions as to coatings I will give some results noticed during the past twenty-five years. During the past month an iron penstock 4 feet in diameter has been removed and replaced by one of a larger size. This one removed was of wrought iron, built of inside and outside sheets, and ordinary riveted lap joints. The penstock was put in eighteen years ago and was thoroughly coated with red lead. It was left exposed to the weather for some months before being painted and placed in position, and the probability was that the interior surface might have been somewhat rusty. I was informed that when it was painted that it was brushed thoroughly with old brooms to make it as clean as possible. Tubercles have formed over about two-thirds of the interior surface in a somewhat irregular manner. They vary in size from $\frac{1}{4}''$ to $1\frac{1}{2}''$ in diameter and project about $\frac{3}{8}''$ to $\frac{1}{2}''$ into the pipe. Their distribution on the surface is not uniform with regard to the top and bottom of the pipe, as in some instances they occur on the top and other places on the sides. On portions of the surfaces free from tubercles the red lead forms a good coating, clinging to the iron. On removing one of the tubercles a depression is found pitted in the iron and of the general shape of the tubercle. This depression varies from .002 to .003 feet in depth below the original surface of the iron. It was probable that the surface was not clean when the red lead was

applied and the action of the water started the formation under the red lead coating.

Numerous penstocks coated with red lead are still in use and in fair condition. One set of four penstocks of about 9 feet in diameter, were scraped and afterwards painted with red lead, about eighteen years ago, and have but few indications of tubercles at the present time. At another mill a penstock 3½ feet in diameter put in nine years ago was thoroughly coated with red lead. The velocity of the water is 1.5 feet per second, and the penstock is covered with slime, and the surface is covered for two-thirds of its area with tubercles ½″ in diameter, and projecting ¼″ into the pipe. It was possibly not perfectly clean when first coated with red lead. After a penstock has become dirty and covered with tubercles there is much difficulty in having sufficient time to clean and dry it thoroughly in order to give it another coat. The surface of the iron should be perfectly dry and clean to make the coating adhere properly. Asphalt varnish is the most generally used and easily applied.

Four iron penstocks, about 150 feet in length, were constructed during 1886. They were each 7 feet in diameter, with butt joints and countersunk rivets, and probably given three coats of asphalt. In April, 1888, they were examined and tubercles had begun to form in all of them, but with no degree of regularity. In some instances sheets covered with numerous tubercles were noticed alternating with others almost perfectly clean, with no apparent reason. The tubercles were about the size of a pea, ranging from two to three in a square inch, and projecting from ⅛″ to ¼″ into the pipe. In general there were more on the top and bottom than on the sides. One of the penstocks which is not in constant use and has the head gate closed, has many tubercles formed on the bottom for about a foot in width where the slight leakage has occurred, but the remainder of the pipe is quite clean. In 1889 a growth of sponge was noticed in small patches in the upper half of the section in the first length of about 50 feet. The recent examinations have shown a gradual increase in size and quantity of the tubercles, and new ones appearing on the top and bottom. The velocities of the water have ranged from 1.5 to 2 feet per second. In 1889 a second set of four penstocks, similar to the preceding, were constructed, with diameters of 7 feet and 9 feet and have been in constant use with velocities from 3 to 4 feet per second. In 1894 a few scattering tubercles the

size of a pea were noticed for the first time in three of these penstocks; in the fourth one the sheets were clean for the first 50 feet, but below this point numerous small tubercles had begun to appear. In all of these cases the asphalt showed a clean surface on the iron, with no cracks or lines of separation except where the tubercles were located, when in taking off the tubercles the asphalt was also removed.

The above penstocks were intended to be of the most thorough workmanship, and to have the best protection known at the time they were put in.

A penstock 5 feet in diameter, put in during 1887, or about eight years ago, was supposed to be coated with three coats of good asphalt. The sheet which I have here (Fig. 1) illustrates the condition that existed last year, of the interior surface. This was an impression taken of the side of the pipe, and shows the irregular shape of the tubercles. The tubercles projected from $\frac{1}{4}''$ to $\frac{3}{8}''$ into the pipe, and this sheet shows a fair average of the condition of all parts of the surface. It has been the intention to have this penstock scraped and cleaned, but there has been the difficulty before mentioned of having the water out for a sufficiently long time to permit of thorough drying. In 1887 a penstock 5 feet in diameter was constructed and put in on the South Canal. I was not able to determine the character of the coating at the time, but have understood that it was coal tar, but tubercles formed very quickly, and a growth of sponge had also attached itself. An examination made during 1886 showed the tubercles from $\frac{1}{4}''$ to $\frac{3}{4}''$ in diameter, and projecting $\frac{1}{4}''$ into the penstock. The growth of sponge was very abundant, and in all stages of development.

Patches from $1''$ to $6''$ diameter adhered to the sides, projecting from $\frac{1}{4}''$ to $1''$ into the interior of the penstock. The general character was a compact mass of reticulated appearance, similar to lace work. Another form was obtained with finger-like tentacles from $3''$ to $4''$ in length, projecting into the penstock, and resembling branch coral. The color was a dirty white, changing during a freshet to a brownish color from the sediment in the water. When exposed to the air it decomposed rapidly with a very disagreeable odor. The sponge was most abundant in penstocks at the lower end of the South Canal where the water was quiet and the velocities through the penstock did not exceed 1.5 feet per second. On the

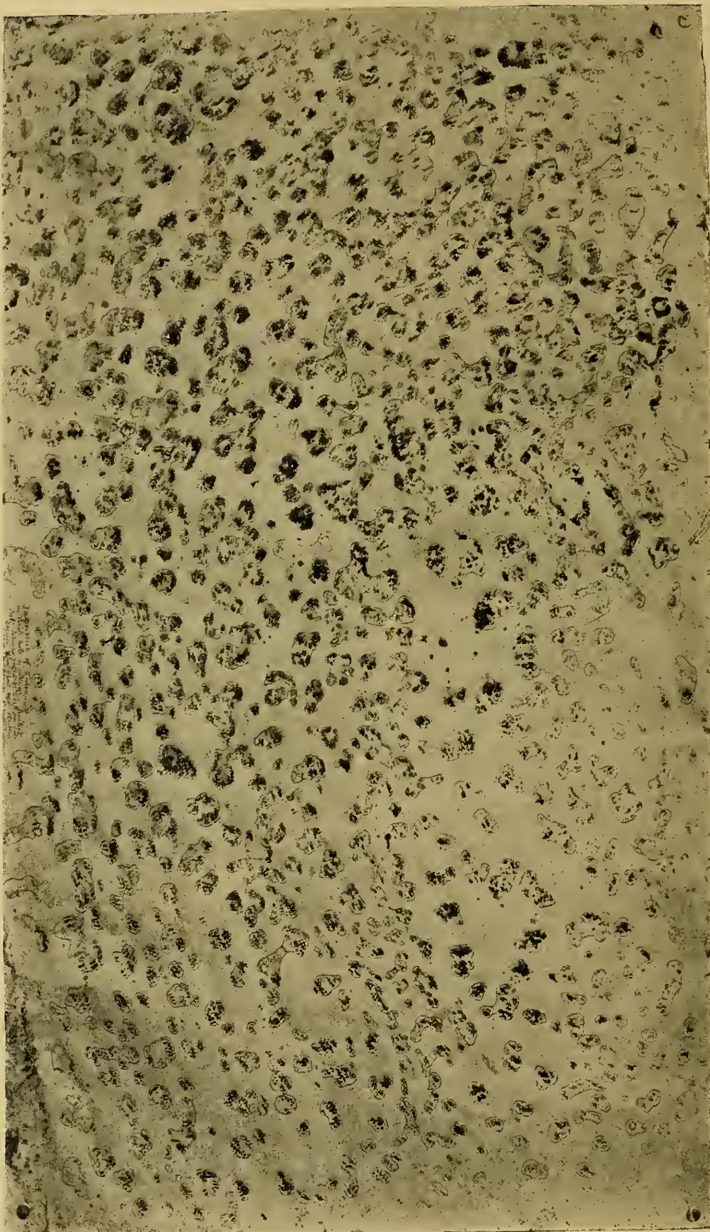


Fig. 1.

North Canal much smaller quantities have been found. In wooden penstocks much less growth has been found, although it may be probably due to location and higher velocities than the character of the surface. In 1893–4 very small quantities were observed, and last year only slight traces of it were found. It apparently grew equally thrifty whether attached to the tubercles or smooth coating of an iron penstock.

One other penstock to which I wish to call attention is located on the South Canal. It is made of wrought iron with inside and outside laps, about 6½ feet in diameter. It is about 250 feet in length and was put in during 1881. I was fortunate to find the party who coated the interior of the penstock, and the following facts were ascertained:

The material used was coal tar used in roofing mixed with a composition tar obtained from the gas works; equal portions of each were used. This mixture was heated and applied hot with brushes to the interior of the penstock as it laid on the ground before being put in the trench. The weather was cold at the time, and no facilities were had for heating the pipe, which was therefore quite cold. The condition of the pipe at the last examination, during last year showed a few scattering tubercles on the lower half of penstock about ¼″ diameter and projecting about ⅛″.

The surface in general is very clean and has preserved its coating of coal tar in excellent condition. The growth of tubercles has been remarkably small compared with other penstocks with asphalt and red lead coatings.

The coating of tar can be chipped off by striking with a knife, showing a thickness of about .002 feet. The result of the coating in this penstock is in striking contrast to the preceding one described, which was also coated with coal tar, although nothing definite is known about its composition or application.

The character of the surface when the material is applied is of great importance to the preservation of the material, whatever coating is applied, and the varied experience shows that great care must be used in its application. In regard to other coatings, a steel penstock 8 feet in diameter and 200 feet in length has just been completed during the last month, and was coated with three coats of asphalt varnish, made by Webb & Co., which is claimed to be superior to the asphalt as usually applied. It will be of interest to notice

if the tubercles will form as rapidly as on the penstocks with other coatings.

A valuable paper has just been presented by President Fitzgerald before the American Society of Civil Engineers on the flow of water in pipes in which the condition of the interior of the cast iron pipe is referred to, and that the tubercles had a small central point of attachment and spread out over the coating, which was not disturbed. As far as noticed in the Lawrence penstocks in removing the tubercles the coating is also removed or destroyed of the same area as the size of the tubercle.

Many of the members will recall the interesting trip to Kendall & Sons, in Cambridge, to see the Sabin Process of coating the 36-inch pipe that is used by Cambridge in its new supply. It will be of great interest to hear from Mr. Hastings in regard to the character and life of the coating from which so much is expected.

In closing, the only conclusion that can be drawn is that great care must be used in the application of the material used, and that the surface of the iron or steel must be bright and clean and free from any rust. The coal tar has shown excellent results in one instance and very poor in another, and in such cases there may have been a difference in the surfaces to which they were applied. The cost of red lead is probably double that of asphalt or coal tar, and the results do not always warrant the increased cost. The experience of an old boiler maker for the past 25 years will be of interest. He says that the very best paint for penstocks to stand wear is coal tar put on hot; the next best paint is red lead and oil mixed as thick as it will run. Two coats of either, well put on, will give the best satisfaction.

To those who wish to pursue the subject farther, I would refer them to papers of M. P. Wood, Esq., of the American Society of Mechanical Engineers, and read at the meetings of June, 1894, December, 1894, and June, 1895, on the subject of Rustless Coatings for Iron.

DISCUSSION.

In reply to questions from Mr. Winslow, Mr. Hale stated that as the water passing through the penstocks of the Essex Company was used only for manufacturing and not for drinking purposes, no observations had been made as to whether or not it was affected by the red lead coating on the iron.

Mr. Brackett thought that the reason why coal tar acts as a preventive against the growth of tubercles in some cases but does not do so in others is because there are so many kinds of coal tar. Anything that is black goes by the name coal tar. He was also of the opinion that sufficient attention has not been given to the coating of pipes, which is a subject worthy of careful study. The results of Mr. Fitzgerald's recent experiments show, that the capacity of pipes may be decreased 25 per cent. in 15 or 16 years, and mean a most serious loss, and if a coating which will prevent this can be found, it is worth a great deal to any place or to any man who can discover it. He stated that he was making some investigations as to the coating of pipes for the Metropolitan Water Board.

Mr. Hammatt asked for the experience of members as to the use of paraffine for the coating of pipes. No response was obtained.

At the request of Mr. Walker a gentleman from Winchendon told of a pipe which had been down over 30 years and which had maintained its full capacity. It was an inch gas pipe originally unlined, and in three years it had become quite filled with rust. He took the pipe up and heated it and shook the rust out, and afterwards dipped it in some tar with which he was covering a roof, and put it down again, and the pipe is still in good condition. The case was particularly interesting, as the pipe had rusted badly before the tar had been applied to it.

In reply to a question from Mr. Fuller, Mr. Hale stated that he had not observed any special difference in the protection, whether the coating had been applied to the metal before it had ever rusted, or whether it had first rusted slightly and afterwards been coated. In general it was intended to have the iron in a first-class condition and with a clean surface free from rust when the coating was applied.

THE APPEARANCE OF CHARA FRAGILIS IN THE RESERVOIR OF A PUBLIC WATER SUPPLY.

BY

F. F. FORBES, Superintendent Brookline, Mass., Water Works.

[Read Feb. 12, 1896.]

As far as I am able to learn, no trouble in water supplies in this country has been traced to the aquatic plant, Chara Fragilis, until the past season, when a case of this kind was brought to the attention of the writer. One reason for this lack of knowledge may be that Chara Fragilis differs from most of the other organisms which cause unpleasant tastes and odors in water supplies in this particular, that it is not free swimming, but attaches itself by small rootlets to the bottom or sides of a reservoir or pond, and usually remains in one position during its life. Its comparative slow growth, coupled with the probability that during its earlier stages it is a harmless water plant, may further explain the dearth of information on the subject.

In the manner of its development it usually forms paleish green patches on the bottom of the bodies of water in which it lives, four or more feet in diameter and two or three feet high. These patches are made up of numerous long, thin stems, perhaps a sixty-fourth of an inch in diameter, bearing whorles about two inches apart of six to twelve needle-like leaves. The stems and leaves are usually covered with a calcareous incrustation.

It has been stated that the plant holds itself in place by small rootlets; these are not true roots, however, but simply a means of holding on, and this plant in common with the Algæ, receives its food directly into the plant body from the water in which it grows.

Chara Fragilis, however, requires a certain amount of lime in solution, and without this mineral solution it will not thrive; we should not therefore expect to find it in waters like that supplied to

the City of Boston for instance, or in fact in many other waters of New England, but may expect it in limestone countries.

The odor it imparts to water is an exceedingly disagreeable one, and one not easily forgotten.

There are many other species of the genus Chara, but most of them are perfectly harmless, or at least no more objectionable than lily pads and similar water plants. The genus Chara is a very old one; some species occur in a fossil state in the Secondary (Jurassic) strata, and in the Tertiary of Europe they are very abundant.

The following description is copied in part from a standard Botany of Thallophytes: "The Characeæ consist of only a comparatively small number of species. The presence of certain species may be detected by the foetid odors of sulphretted hydrogen given off when decaying. Some authorities attribute the odor to the presence of a special substance called characin. The typical genus Chara is distinguished by its power of extracting calcium carbonate from the water in which it grows, the whole plant becoming thus covered with a calcareous incrustation."

A brief description of the case which forms the subject matter for this paper is as follows: The water supply of a city in a neighboring State became very unpleasant to drink last August. The cause of the trouble was not apparent to those in charge and the writer was asked to make a personal examination of the different reservoirs, and if possible locate the trouble. The water in all the reservoirs except one was found to be good, and this one had considerable shallow flowage. The bottom of the shallow parts were nearly covered with a growth of Chara Fragilis. It became evident to the writer that the whole mischief was caused by this plant, and later information has fully corroborated the conclusion reached at that time. The reservoir in question was at once drawn off and the plants removed, since which time the water has been uniformly good.

DISCUSSION.

In answer to an inquiry from the President, Mr. Whipple stated that he had never met the organism mentioned by Mr. Forbes. Mr. Forbes stated that the reservoir mentioned was in Central New York and that the water was quite hard. He further stated that in parts of Europe much trouble is experienced from this plant, but that this was the first case that had come to his attention in the United

States. He was quite sure that the trouble was due to this organism and not to any other matter which might have been stirred up in cleaning the reservoir. The bottom of the reservoir was irregular, and it was only found in the places that were comparatively shallow and it apparently depends for its growth upon the light that gets through the water. The bottom of the reservoir was of clay and had not been cleaned for a long time; there was but little mud upon it. The stems grow several feet long and the bottoms of the plants may be decaying while the upper portions are still growing. There is but little odor while the growth is still active, but in this case the odor from the whole mass was very unpleasant.

RECORDING PRESSURE GAUGES—THEIR USE AND ADVANTAGES.

BY

FRED. G. PERRY, Pawtucket, R. I.

The subject of recording pressure gauges is perhaps old and now little discussed, but to me, to whom the matter is comparatively new, the study of the gauges and their records is exceedingly interesting.

On the system of the Pawtucket Water Works we have seven Edson recording gauges in constant use ; five are for recording water pressures and two for recording steam pressures on boilers. An eighth gauge we use as a spare one to replace any of the set gauges that may be removed for any cause, as for adjustment or cleaning. Gauges are located at each of the pumping stations, at the main office of the Department, which is in the center of the city, at the construction shop, which is near the river, and at the office of the Pawtucket Manufacturing Company, which is west of the center of the city.

The gauges and charts are set in places convenient to the sight of interested parties during the entire day, and we are made aware of unusual draughts, leaks, etc., ofttimes very promptly. We are sometimes warned of the existence of a leak half an hour before the location is reported to us. In the meantime we have prepared ourselves and are ready to respond quickly. To the engineer in charge of the pumping stations the gauges have become invaluable. By means of them he has a constant and permanent record of the pressures maintained at each point, and any unusual fluctuation is noted and inquiry immediately instituted to find the cause.

In very dry times some of our large factories, especially those which have departments for dying and bleaching, call for large quantities of water on short notice, or rather without any notice, and in such cases the gauge performs a valuable service. For

instance, a sudden drop of 10 pounds in the normal pressure of 120 pounds is noted at the pumping station. The engineer at once telephones to the office and reports the same, with an inquiry to know if we have noted the drop on our gauge, and if we know of any leak or heavy draught. Sometimes we are aware of the cause and state the same to him, and he governs himself accordingly. If we are not aware of the cause we at once take steps to inform ourselves, and generally we succeed in finding it. We at once communicate with the parties where gauges are located to inquire if any drop in pressure has been noted by them, for by this means we are sometimes enabled to get a correct idea of the locality of the draught more quickly; we then set out to find the exact locality and the reason for the unusual flow.

Complaints of a lower pressure than usual from firms using the city water for boiler feed, and who feed direct without the aid of pump or injector, are always investigated by means of recording gauges placed on the line from which the supply is taken.

We have had a special gauge constructed by the Bristol Manufacturing Co., of Waterbury, Conn., as we were unable to find in the market a gauge that met our views. The difficulty with the ordinary gauge is that the space between the pressure lines is not great enough to show clearly the pressure in pounds, and also the time scale is too small to show accurately the length of short, heavy drafts. This gauge is portable, and is inclosed in a suitable box or case, and can be attached to a hydrant or faucet or corporation tap by means of a hose, pipe or other convenient means. This is a very useful apparatus, and we should not like to be without it.

In case there is reason to suppose that a party is using water surreptitiously, the gauge is quietly attached at a proper point, the chart is set and the door locked, and another visit is made within twelve hours, and if it is wished to continue the observation, another chart is placed on the cylinder.

If your suspicions are well founded the pressure line recorded on the chart will show to you when the flow occurred, how long it lasted, and by observing the number of pounds drop you can tell very nearly the size of the opening used. You then have in your possession a silent but indisputable witness, and in our experience, when shown to the interested parties, the chart generally settles the argument.

The recording gauge served this department well at the time of the famous trial of fire hydrants on September 19th, 1889, when seventy fire streams were played at once, when, to quote from the 10th annual report of our former Superintendent, Mr. Edwin Darling, to whose untiring energy and zeal the City of Pawtucket is largely indebted for a water works system second to none, "the Chief Engineer of the Fire Department was invited to play seventy fire streams at once, which was successfully accomplished, holding eighty pounds pressure during the time the test was made. The test was made on the twenty-inch force main, three and one-half miles long, leading from the pumps through the center of the city to the storage reservoir on the heights at an elevation of 301 feet above tide water. Four thousand and forty feet of this main were used, and the streams were taken from nine six-wayed and eight two-wayed hydrants. Six Edson recording gauges were placed on the line, located so as to give the best results of the loss of pressure. By the use of these gauges we are enabled to state facts which we should have been unable to do without them. We challenge any water works in the United States to play seventy *one inch* fire streams through fifty feet of hose and maintain eighty pounds of pressure during the trial, the pressure to be verified by recording gauges placed in suitable position on the line of the pipe."

The recording gauge played a highly important part in this test, as it placed on record and beyond dispute in the future the exact pressure maintained.

In closing I cannot do better than to again quote from the same authority, with our hearty endorsement, where he says: "No well conducted water works can afford to be without recording gauges; they not only verify the pressure on the mains, but detect leaks and the opening of hydrants or any heavy draughts of water for legitimate or illegitimate purposes, and, when properly located, they will in my opinion pay for themselves within one year."

DISCUSSION.

Mr. Whitney. I should like to ask Mr. Perry as to whether or not it has been possible to obtain results showing the force and amount of water-hammer, and if so for how long a time would they register. I believe that Mr. Darling had that in mind, and there has never been any special report from him in regard to them.

Mr. Perry. The registration of the gauges is limited solely by the length of the roll of paper put on them. I think they last for about a month as a rule. The gauges I had reference to, which were made for us by the Bristol Manufacturing Company, were ruled for only 12 hours so as to give a greater space between the hour lines and give more accurate records for such short periods as five minutes. With the regulation Edson gauge, which is ruled, I think, for about a month on the chart, the hour spaces are only about $\frac{3}{4}$ of an inch, and a 5-minute flow on that would show a mark on the gauge very similar to that from a water-hammer, which would be all in one continuous line. If the gauge is speeded up enough you get the duration of the flow. You can decide then definitely whether it is due to water-hammer or some one drawing from a 6-inch butt, and in five minutes there is quite a little water drawn if it is under such a pressure as we have. You can decide then whether it is a draft or water-hammer, and that was our reason for having the dial made on a 12-hour scale. A 24-hour scale would be one-half as large. On the gauges Mr. Darling referred to, the hour marks were about $\frac{3}{4}$ of an inch, and if my recollection serves me—I was not connected with the water works at that time, but was with another city department and recollect the test very well—they maintained the flow of water for about eight minutes, and that was as long as the streets would hold it. They could have maintained it till the pressure in the reservoir dropped. I think it was figured at that time that they could maintain that pressure for somewhere between two and three days.

Mr. Haskell. We have a good many bursts in our water pipes, mostly occurring in the night, and they are liable to do a great deal of damage. We keep a couple of men in the stable in readiness to attend to them and to shut off the flow of water as quickly as it can be done. Now, you cannot always depend upon the men to stop these bursts at once, and they may tell you any sort of a story they are a mind to in the morning, and while the bursts may have run a couple of hours it may be reported that they have been shut off in ten or fifteen or twenty minutes. It makes a great deal of difference when a stream of water is running into a house whether it runs 30 minutes or 5, and I think it makes the men a little bit livelier if they know that, whatever their report is, and they always are supposed to report when the leak is discovered and

when it is shut off, all I have got to do is to look on the pressure gauge to see what they have been doing. Perhaps it hurries them up a little bit and makes them do their work more promptly.

Mr. Fuller. I would like to ask Mr. Haskell whether he has any relief valves at Lynn, and if he has, whether they do not prevent breaks?

Mr. Haskell. Wherever there is an elevator or anything of that sort which requires the opening and closing of gates, we put in a relief valve, but not in the streets.

Mr. Fuller. Wouldn't that be a help to you in saving some of your breaks?

Mr. Haskell. I don't think it would at all. Our leaks are not occasioned by the water-hammer. It is a little peculiar condition of water pipes when an additional pressure of one pound is going to cause a pipe to burst, and I almost hesitate to tell you, but I will tell you what we have found. Our pressure at night in City Hall at our gauge runs up to 60 pounds. There is a portion of the time in the night when there is very little use of water, and we hold back the water from the reservoir in part, holding the rest in reserve until there may be a conflagration which needs it. We do not allow our pressure to go below 40 pounds at City Hall in the day time, and it never goes above 60 at night. We put in a large main for fire supply some years ago, and the Water Board were very anxious after this was put in to have the water turned on to see what it would do. I cautioned them against anything of that sort, for I thought in all probability it might occasion trouble. Well, one evening when the Water Board was in session they got anxious and they said they must have it turned on so they could see what it would do. The gate was opened and the pressure seemingly hadn't begun, you couldn't see that it was the second pound above, when we got the report of a break and we had to shut down. Well, there were six breaks before we got through with it, and it cost over $200 to repair the damage caused by that little additional pressure.

Mr. Richards. If I understand Mr. Haskell correctly, he has a difference in pressure of about 20 pounds between day and night. If there is such a difference that might readily account for the great number of leaks reported.

Mr. Haskell. We don't intend to let the pressure go below 40 pounds at any time, and the 20 pounds represent the extreme variation.

Mr. Perry. As a recent instance, I will mention the case of a corporation in town that wanted to use a good-sized stream to bore out a culvert cheaply, and we granted them permission to make a temporary 6-inch connection providing they would report to us the length of time which they used it. They reported that the gate was open about twenty minutes, while the nearest pressure gauge showed a drop of some 10 or 12 pounds in the pressure at the time I knew they opened the gate, and that instead of some 20 minutes they had had it open about 40 minutes. There was a 6-inch stream of water going out at a pressure of 120 pounds for 20 minutes longer than they said, and that is considerable water for a man to borrow.

Another instrument which we have recently installed with great success is a recording gauge for showing the height of water in our Stump Hill Reservoir, which is our pressure reservoir, having a capacity of about 20,000,000 gallons.

Mr. Holden. What kind of a gauge is this you have at the the reservoir?

Mr. Perry. It was made by Mr. George E. Winslow. We had this gauge in operation in the tank in the shop about a month before we put it into the line and it worked to absolute perfection.

Mr. Coggeshall. I think I should like to ask Mr. Perry with reference to leaving his recording gauge near a hydrant. Do I understand he puts it in the box and leaves it connected with a hydrant in the public street?

Mr. Perry. The Bristol gauge, with which I presume many of the members are familiar, is a flat gauge and can be put in a box which slides under a buggy seat. The other gauge required a square box, and it was bulky. We enclose it in the box so we can lock it up, and, if necessary, we leave it on the street, but when this is done we leave a man with it. It is in a good, substantial box, in the form and nearly the size of a dress suit case, and is much more convenient than the other form.

Mr. Chase. One allusion of Mr. Perry's touches a familiar subject in my own experience, and I presume in that of others. I refer to the apparent baneful effect the use of water has upon veracity. No matter how irreproachable a man's morals may be, as soon as he becomes a consumer of water than he loses all desire for truthfulness, and will often go beyond that and help himself to his neighbor's property without let or hindrance. There seems to

be a field open for this Association when it shall have done all it can to aid in the furnishing of irreproachable water, and that is in the inculcation of irreproachable morals on the part of consumers, so far as the taking of water which does not belong to them is concerned.

Mr. Perry. If you will indulge me once more, Mr. President, we recently had reason to think we were not getting paid for all the water a certain consumer was using. We talked with him in a friendly and confidential way, and he was very sure that no water was used on his premises but what came through the meter. He took his supply through a meter, but there was also a fire supply through the corporation premises. We investigated, and found that at times they had from one to three lines of 2½-inch hose attached to the fire hydrants and played them directly into the vats of the concern. He was very loathe to believe it, in fact he would not believe it. He said his men told him that they did not use those hydrants, and Mr. so-and-so had been with him for 20 years, and he would believe what he said. Well, we followed it up by attaching the pressure gauge and we got the positive record on the chart, and when we got it where we wanted it we called him to the office. The result was he found out that his employes had used the hydrants without his knowledge or consent, and he very promptly settled for it and saw that the use was discontinued.

Mr. Fuller. I would like to inquire how near the recording gauge was located to the premises in this particular case?

Mr. Perry. Within about 500 feet.

WATER FILTER AT THE MILFORD WATER WORKS.

BY

Frank L. Northrop, Superintendent.

[Read March 11, 1896.]

The water supply for Milford is from wells, of which there are three about 25 feet in diameter, also a basin on the Charles river from which the water for fire purposes has been drawn. Since the construction of this filter, however, there has been water enough from the wells and filter for all uses.

For some years past the supply from the wells has been low during the summer season for about five months, the balance of the year they have supplied a quantity sufficient for domestic and manufacturing purposes.

When low we were obliged to draw from 300,000 to 400,000 gallons of unfiltered water from the river basin in which was considerable sediment and color. In the spring of 1895 we concluded to put in a sand filter which was constructed as shown by the blue prints present.

The construction was begun by excavating a hole in the ground about 225 feet long, 9 feet deep, and from 20 feet to 50 feet wide. The bottom was graded toward the middle and from each end toward the center, and from the center toward the well, so the water would run by gravity into this well. Having completed the grading we laid the tile pipe of various sizes with open joints—the pipe entering the joint about $\frac{1}{8}$ inch. Small cobble stones about 2 inches in diameter were then carefully placed by hand over all the pipe and bottom, as shown on section drawing.

From this the size was graduated to $\frac{1}{16}$ inch, which we got by screening. Sand was then filled in to a depth of about 5 feet, and graded from each side up to about 8 inches higher in the center.

A brick gutter was laid around the edge from the settling basin to prevent washing the sand when the water enters from said basin.

This settling basin is supplied thus, a pipe from a gallery in the Charles river basin, built to prevent the mud from washing in—a serious drawback which we have to overcome.

We use the middle of the three wells for a gallery. This gallery is connected by a brick conduit with the well nearest the pumping station, from which the water is pumped. The supply pipe from the filter runs into the well about 15 feet from the bottom. The quantity of water supplied by the filter is regulated by a 15-inch gate, as shown on the blue print.

We found by filtering the water through 5 feet of sand that practically all the color and river silt were removed, making it nearly as clear as well water, which is considered very good. We are also enabled to keep our wells up from 6 feet to 12 feet all the time, thereby saving much of the lift we have always been obliged to encounter. The wear and tear on the pumps is much less, which is a saving and a great benefit to pipes and machinery generally. Our lift previous to building this filter was from 26 feet to 28 feet. By experimenting with this filter we find there is no trouble with air although but one grade of sand was used. We account for this by proper handling. By letting the water down a while at night and allowing it to filter through the lowest part, leaving about one-third of the highest part uncovered, and then letting water on very slowly, the filter working at the same time so as to drive the air up through the center, that air is expelled and the filter will run longer without cleaning.

The cost was about $800, but would have been much more had we not had the sand and stone on hand.

DISCUSSION.

Mr. Haskell. I would like to ask if there was any analysis made of the water at any time before it entered the filter and after it came through, to see how the filter operates.

Mr. Northrop. As the water in the river analyzes very good I haven't gone into it particularly. The dirt was what we were trying to get out, and as we could see the filter did that we haven't had the water analyzed at all. It certainly took most of the color out; there was some little color left, but mixing the water with the well water "half-and-half," made it look nearly as clear as the well water itself, which is very clear.

Mr. Thomas. I would like to inquire of Mr. Northrop if he has any trouble with the filter freezing, or how he prevents it from freezing?

Mr. Northrop. When we put this in we didn't put it in for winter use, as we have water enough in the winter time, but as our engineer and firemen don't like to work any more than anybody else, they have run it all winter with ice on top of it. As the people in the town haven't found any fault we have in that way saved coal and labor.

Mr. Fuller. I would like to ask Mr. Northrop how often he has to clean this filter?

Mr. Northrop. Last summer, when we were running on an average of about 400,000 gallons, and by the way, this filter is only about a quarter of an acre in extent, we cleaned it out about once in six weeks. It took four men about a day to clean it. Since last fall we haven't cleaned it at all, and I should say it is now getting clogged up some, but of course there isn't as much sediment in the winter as in the summer, and I think there are now about 100,000 gallons a day going through it. Last December was the last time we cleaned it.

Mr. Thomas. I supposed it would be impracticable to clean it in the winter without taking the ice off, and my object in inquiring was to find out if he had any means of taking off the ice.

Mr. Northrop. I don't see how it could be cleaned without taking the ice off, and we haven't cleaned it, as I say, because we have water enough without it in the winter.

Mr. Chace. I would like to ask Mr. Northrop a question which hasn't anything to do with the filter, but as he has a direct pumping system, I would like to inquire how many fires he has had that he could not take care of without fire engines.

Mr. Northrop. I couldn't answer that question exactly, because we have always used fire engines; that is, we have two engines in town and one is always run out in case of fire. But a great many times I have wished it had been left in the house, because it is attached to one side of a hydrant and then they complain because they don't get a good stream from the other nozzle. I do not think there has been a fire in town in the six years of my administration that we could not have handled, and there isn't a building there we couldn't throw over. We have 150 pounds pressure at the lowest point, and that is all the firemen want.

ANCHOR ICE.

BY

R. C. P. Coggeshall, Superintendent, New Bedford, Mass.

[Read March 11, 1896.]

The Mt. Pleasant distributing reservoir of the New Bedford water works system has been used since water was first introduced into that city in 1869. Its inside dimensions at the flowage line are about 425 by 335 feet, and when full it contains 15,000,000 gallons, and the water is 18 feet deep.

In connection with this reservoir there is a gate-house, which is located at the foot of the inside slope wall, and about midway along the easterly side. It contains two chambers. The northerly one is kept dry, and through it passes the original 16-inch force main which formerly discharged very near the opposite side of the reservoir. The southerly chamber contains the screens through which water passes to the distributing mains.

Eleven years ago a second force main, diameter 30 inches, was placed from the pumping station to this reservoir. It passes over the easterly embankment and discharges over a weir located in the slope wall, at the space between the gatehouse and the top of the slope. After this second force main was laid, the original 16-inch force main was so connected, and gated, that it may be used at discretion, either as a force or distributing main. When there is reason to do so the pumping may be direct into the distributing system, and the surplus water in this case, passes through the screen chamber into the distributing reservoir. That it is occasionally necessary to adopt this method of pumping, will appear later.

With this brief description of the conditions which exist, I now come to the experience which is the title of this paper.

Occasionally during the cold weather of past years, under conditions which are well understood, the supply of water from this reservoir has been suddenly cut off, by reason of "anchor ice" forming a complete barrier in and around the screen chamber.

When the conditions are ripe, it quickly solidifies against the screens suddenly forming an ice dam, and preventing all passage of water. That remaining in the lower side is quickly drawn away by the consumption of the city. Thus, a pressure is almost immediately established against the screens, under which they invariably yield and become badly wrecked. The ice then rushes into the open ends of the distributing mains, choking them, and completely cutting off all connection from the distributing reservoir.

Several years ago, when the works were in their infancy, this trouble was a much more serious matter than now. It always occurred well into an extremely cold and blustering night, when the waste of water to prevent freezing, added to the regular legitimate consumption, caused a considerable portion of the distributing system to be completely emptied before the trouble was discovered. This was some years before telephones were in use, and consequently a long time would ensue after the first discovery, by some consumer, that he was deprived of his supply, until the superintendent was called from his bed, and he in turn had collected his men at the scene of action. In those days there was not so much known concerning the mysterious movements of this troublesome visitor, in connection with reservoir supplies as now, and when the superintendent was notified of the failure of the supply, I imagine that he was puzzled to account for the cause, and probably considerable time may have been lost on account of this uncertainty. I remember one occasion, about 1873 or 1874, when the water had been cut off during the night, that at 10 o'clock in the morning no water could be drawn at the city hall, and it was some time later before the pressure gauge began to indicate that the supply was returning. In those days the average daily consumption was light, and a few hours each day sufficed to do all the needed pumping, consequently no employe was retained at the pumping station over night.

A few experiences like that just related convinced the Water Board that a watchman at the gatehouse of this reservoir through the coldest nights was a necessity. It was thought that he might prevent the formation of the solid mass of ice against the screen by breaking it up and stirring it with long poles and rakes. His efforts in this direction proved entirely futile, and the only good which he rendered was to call for help, when the trouble occurred, with as little loss of time as possible. It was now noted that this trouble

would not occur when the surface of the reservoir was covered with ice.

Then came the early days of the telephone, and increase of work at the pumping station soon led to a night watchman being retained there. A pressure gauge was fitted with an electric alarm which rang with a few pounds reduction of pressure. This warning bell has since proved useful on several occasions. As the unwelcome visit has always occurred during the night, it would be at a time, during the earlier years of the works, when the pumping machinery was not working.

It was found, however, that a supply could always be obtained through the 16-inch force main which had its opening, as previously stated, on the opposite side of the reservoir from the gatehouse, or on the windward side during this trouble. This seemed to indicate that while the ice crystals were forming upon the water surface at all parts of the reservoir, to a greater or less extent, this action was intensified at the extreme lee side, where the agitation of the water by action of the wind, was of course much more vigorous. Here all the rapidly forming crystals seemed to be driven by the wind and huge masses would soon collect.

During the past ten years this trouble has been cared for wholly by the pumps, which are then changed to operate directly into the distributing system, and if possible, to create enough pressure to drive the ice back from the screen chamber. The screens are, however, apt to be more or less damaged whenever this phenomenon occurs. The fierce wind and strong lower currents carry the crystals to the bottom portion of the screens and gate chamber, where they quickly adhere, before their presence would be apprehended by surface appearances. At such times an attempt to remove the screens is often met with failure, by reason of their being held firmly in place by the ground ice formation. In such cases the ice quickly collects and the barrier is soon completed and the destruction of the screens assured.

When this does occur then the connection with the reservoir is made by means of the old 16-inch force main as heretofore described. If, however, the screens can be removed, then the warmer water from the pumps through the distributing system soon forces a passage, making a tunnel, as it were, through the barrier of ice completely filling the gate chamber. Thus the ice may remain attached

to different portions of the gate chambers for two or three days, but there seems to be no trouble in keeping this tunnel open through into the reservoir, as long as the pumps are kept in motion, and pumping a little more than is being consumed.

The consumer is, however, no longer aware of any difficulty as the pressure upon the mains is not allowed to drop many pounds before it is again regained by the pumps. During the past ten years we have had seven visits, and the ice within the gate chamber after it has formed, has remained from one to three days.

The following statement regarding anchor ice and its formation is extracted from an article which appeared several years since, in the *Journal of the Franklin Institute*, and is from the pen of that distinguished hydraulic engineer, the late James B. Francis of Lowell:

"Anchor ice is an aggregation of small crystals or needles of ice, forming in the water a spongy mass, easily penetrated with any hard substance. It is frequently found adhering in large quantities to the bottom and sides of the water courses, both open and covered. In clear weather, as the sun approaches the meridian, masses of anchor ice often rise from the bottom of the open channels and float off, sometimes with earth and small stones adhering. It is produced in the greatest abundance in cold, clear, windy nights. It unquestionably originates at the surface of the water, the necessary conditions being that the water should be at the freezing temperature, the air below that point and the surface of the water agitated, either by a current or by the wind. In its first stage the ice is in small detached needles or crystals; if there is little or no current this ice accumulates at the surface and finally consolidates into a sheet; if the current is too strong to permit this, portions of it accumulate in spongy masses, and float along at or below the surface, their specific gravity differing but little from that of the water. In a current of water there is a constant intermixture of the water at different depths, producing a uniform temperature at all depths, and tending to distribute uniformly foreign matters held in suspension. This takes place even in the most uniform and regular channels. Natural water courses are almost always irregular in form; the more irregular the more rapid will be the intermixture.

"The anchor ice being formed in small crystals at the surface, by means of this intermixture, much of that which does not aggregate in masses is carried down from the surface, and is distributed

throughout the whole depth of the stream, much in the same manner as earthy matters are carried along in suspension by currents. These crystals have a strong tendency to adhere to each other or to any other solid bodies they may come in contact with. The adherence can only take place by freezing, that is, by a new formation of ice, and here lies the mystery of anchor ice. How can water become ice without a loss of heat?

"Anchor ice is observed to adhere to surfaces of stone or wood, over which the water is running with considerable velocity, in some cases exceeding 20 feet per second, growing up under this rapid current at the rate of an inch or more per hour. It is clearly not dependent upon radiation in the manner Dr. Wells has shown dew to be formed, for we find the piers of bridges and the interior surfaces of subterranean water courses, where there can be no loss of heat by terrestrial radiation, covered with anchor ice.

* * * * * * *

"Anchor ice commences to form at the surface of water, agitated either by a current or by the wind. The water being at the temperature of 32° Fahr., and the air at a lower temperature, heat passes from the water to the air, equivalent to the formation of a certain amount of ice; the water being agitated and the ice in minute crystals, the latter become mixed with the water before all the ice due to the loss of heat is formed; and, although the crystals are removed from further loss of heat, they will continue to enlarge, until an equilibrium is attained. The amount of ice formed after the crystals leave the surface may be very small, but still be sufficient to cause them to adhere, when, by means of the current, they are brought in contact with each other, or with any other solid at the freezing temperature.

"If this explanation is correct, the freezing process must continue for a considerable interval of time after the crystals leave the surface, as we have found on drawing the water out of a subterranean water course, the whole interior surface of the channel coated with anchor ice, with great uniformity and symmetry, and several inches in thickness. This ice must have formed before it entered the subterranean channel and subsequently adhered."

Our late esteemed member Gilbert Murdoch, Esq., formerly superintendent of the water department of St. John, N. B., had an experience of unusual interest, when, on November 22d, 1880, the works

under his care were rendered useless for 15 hours by reason of the sudden appearance of this ice in the distributing screen chamber.

He made this occurrence the subject of a special report of considerable length to the city government of that municipality. This document is of more than usual interest.

In this case the lake from which the supply is taken was covered with ice, with the exception of a strip of open water about 100 feet in width along the shore in front of the gate house through which the supply to the city passed. This open water was kept from freezing, though its temperature was doubtless below 32°, by the gusty gale which had been blowing for many hours. Here the ice formed and was drawn into the gate house by the inflowing current, gradually collecting and solidifying, until the obstruction to the flow was complete. The supply was restored by removing the screens and cutting an opening through a plank partition which held the frame work of the screens and divided the gate house into two compartments. The aperture thus created allowed the ice mass in the upper gate chamber to pass through to the lower chamber where it found an easy egress through waste gates. As the aperture was enlarged the velocity became sufficiently rapid to destroy and carry out all the ice which had collected in the upper chamber, and ultimately to bring a warmer body of water to the gate house from under the ice covered parts of the reservoir. The danger was now passed, and the waste gates were sufficiently closed to allow the water to rise to its normal height within the gate house, and the refilling of the supply mains begun.

Mr. Murdoch summarizes the conditions under which this ice will form as follows, viz.:

"(1) That ice will and does form in open water under certain meteorological conditions; (2) that at such times it is found floating in fine particles at various depths from the surface; (3) that it adheres readily to all solid bodies with which it comes in contact; (4) that it grows or aggregates rapidly when once it has secured a center of crystalization; (5) that it not infrequently closes submerged culverts and water courses, as well as open canals and aqueducts; (6) that the conditions most favorable to its rapid formation are, open water at or below freezing, a sky clouded by day and clear by night, a high wind, and an air temperature ranging from about 5° to 20° above zero; (7) that it seldom forms in bright sunshine, but

on the contrary is often loosened by this influence and is seen to rise in masses to the surface; (8) that it is less troublesome when the mercury is at or below zero than at higher temperature, and (9) that the trouble ceases as soon as *the surface of the water is firmly frozen over.*"

In the case of New Bedford should be added the condition that the wind must be blowing from the west to north for several hours previous to the formation of the ice. The conditions have never been right for its formation there when the wind has been in any other direction.

After the trouble has commenced the wind may change, carrying the bulk of the ice to the south or even to the southwest corner of the reservoir, but under no condition has ever a trace of ice collection been observed in the northwest corner.

The conditions under which this ice will form have already been fully described, but it may be of interest to have a detailed statement of the meteorological conditions in a single instance as observed at New Bedford placed before you.

1894.	Wind.		Temperature.	
	Direction.	Velocity. Miles per Hour.		
Dec. 27....	NE–SW–NW	from 14 to 29	from 52° to 26°	
" 28 . .	NW	" 10 to 15	" 28° to 9°	
" 29....	NW	" 15 to 18	" 17° to 7°	Ice barrier formed at 10 p. m.
" 30....	W to SW	" 3 to 17	" 9° to 30°	
" 31....	N to NW	" 1 to 6	" 20° to 28°	

The weather during this period was from fair to cloudy.

The barrier formed upon the screens in this case about 10 o'clock of the evening of the 29th, and it was three days before the ice fully disappeared from the gate chamber.

The supplies to the cities of Chicago, Cleveland, Detroit, Montreal and other places have been seriously interrupted in the past by this ally of Jack Frost, and reports which later appeared, descriptive of their experiences during this period which must have "tried the souls" of the officials, are of value.

A very interesting case is related by Mr. James B. Francis in a paper presented to the American Society of Civil Engineers in December, 1886. It relates to a disturbance of the supply to the Carleton district of St. John, N. B.

It occurred in the distributing reservoir of a capacity of about one and three-quarter million gallons, being 18 feet deep when full. This reservoir was receiving its supply, when the trouble came, through a 12-inch pipe at the rate of about 300,000 gallons in 24 hours, with the water drawn down about 10 feet, leaving a depth of water and ice of about 8 feet. The reservoir was entirely frozen over with the exception of an area of two or three hundred square feet directly over the supply pipe. The ice covered parts were about 6 inches thick.

Mr. Francis says: "On the evening of December 8th, 1882, the supply of water to this district suddenly ceased, and so continued for a short time until other connections were opened. On the following morning a hole was cut in the ice, which was about 6 inches thick, immediately over the outlet pipe, where a mass of ice was found, which is described as a kind of slush or minute particles of congealed water; on prying upon it it floated up, and the bottom of it was exactly the shape of the strainer of the outlet pipe, showing that it rested upon it and completely closed up the outlet. The strainer is a copper rose, perforated with holes about one-fourth of an inch in diameter, the marks of which appeared upon the ice. The whole column when taken out, or as much of it as would hold together, was about the size of a barrel, and was composed of minute particles of ice, all standing on end, firmly adhering to each other. On removing this ice the water commenced to flow to town as usual."

Mr. Francis reasons that the discharge of the inlet pipe "must have produced an agitation in the part of the reservoir near the inlet pipe in the form of eddies in various directions, some of them extending to the surface, and the temperature of the entering water being above the freezing point, the result was the open water of two or three hundred square feet over and near the inlet pipe."

He concludes that the "ice which closed the strainer formed on the open water over the inlet pipe, was carried under the ice by eddies and currents, and continued in motion until it reached the strainers."

The conclusions which are drawn from the New Bedford experience may be thus stated:

First—Anchor ice will not form when the surface of the reservoir is covered with ice, therefore if the surface could be permanently covered, shielding the water from the action of high winds, anchor ice would never form.

Second—When it does form, as the winds are always blowing from a northerly or westerly direction, accordingly the troublesome ice masses will always be found on the easterly and southerly sides, while the windward side of the reservoir will be found entirely free of this formation.

If, therefore, the supply for the distributing mains should be taken during these occurrences from the northwest corner, there would seem to be little chance of a stoppage of the supply by reason of anchor ice barriers.

In the design of the new distributing reservoir for the New Bedford Water Works, now under construction at High Hill, in the town of Dartmouth, the engineers, Messrs. Rice and Evans, having this trouble in view, have located the effluent gate-house midway upon the westerly side. This reservoir consists of two basins, each 500 feet square, internal measure. The effluent gate-house will take its supply from the northwesterly corner of the southerly basin, and from the southwesterly corner of the northerly basin. During the anchor ice period it is proposed to draw wholly from the southerly basin.

The question may be asked if the current created by the passage of water to the distributing mains will not tend to draw the anchor ice to the chambers of the effluent gate-house, although located in the northwest corner.

In reply I would say that it is true that in both the Carleton case described by Mr. Francis and the Portland case stated by Mr. Murdoch the supply was taken from the west side of the reservoir. In the Carleton case the trouble occurred under an ice surface six inches thick, and the peculiar conditions attending the formation would have been likely to have allowed the formation of this ice upon the strainer of the outlet pipe whatever part of the reservoir its location might have been. In the Portland case the floating ice crystals found their passage into the gate-house against the prevailing gale. The wind could do no more than carry it to the lee side

of the comparatively narrow strip of open water in front of the gate-house, which was probably not so far away as to prevent the ice collection when it sank beneath the surface from feeling the influence of the current toward the gate-house created by the draft of the distributing main. If the entire lake surface had been open water, possibly the result would have been different, as the gale would have then had an opportunity to have driven the ice formation far away to the lee side of the lake.

Besides there is a vast difference in the winter temperature of New Bedford as compared to St. John. It is seldom that the surface of the New Bedford reservoir is ever frozen. If it does so happen, the ice is very thin and is short lived. So I do not think any current such as might be created by the draft of the distributing main will be sufficient to overcome the action of the strong northwest wind which will then be heavily blowing, while a change of wind to the southeast such as would tend to drive the ice toward the gate chambers is always a warm wind with us and would cause the anchor ice to quickly disappear.

When we have had occasion in the past to draw the supply through the old force main from the westerly section of the reservoir the current did not in the least change the mass of anchor ice from its location upon the easterly side.

Neither does the incoming current from the screen chamber, caused by pumping through the distributing system, drive the anchor ice away in face of a strong westerly wind, and only in a limited way does this current maintain an opening through the ice barrier into that basin as heretofore stated. But the ice stays there as long as the wind remains unchanged.

A change of wind will, however, quickly drive the ice from the gate-house. I have known it to be completely blocked, when a sudden change to an easterly wind would clear it and drive all the ice to the south side of the reservoir. At this time we were deluded with the belief that the trouble had had its run for that time, but the next night a change of wind to its original direction brought back all the ice and packed it into the screen chamber a second time in face of the current flowing into the reservoir from the pumps. From this reasoning we are of the opinion that a supply taken from the northwest corner of the new reservoir basin will never be obstructed by the formation of anchor ice.

We have never had trouble from this annoyance at either the storing or receiving reservoir of our system, and thus our experience is wholly confined to the distributing reservoir, as has been described.

DISCUSSION.

Mr. Richards. We have had several appearances of anchor ice at New London and the conditions were about as described by Mr. Coggeshall, with the exception that there was always a sudden fall of temperature, from warm to cold, not necessarily very cold, but, say, to 20 degrees above zero. The particles, as I have observed them, have been about the shape and size of a silver dollar, and the entrance to the gate-house, which was at that time about 10 feet deep and 12 feet wide, was completely blocked with them. It was more like "sposh" than like solid ice; if you ran a pole into it, it would be difficult to draw the pole out. The other phenomena connected with it were very similar to what Mr. Coggeshall has described.

Mr. Hale. At Lawrence we have had some very interesting experiences with anchor ice when the river is open. If the river is frozen over we usually have no trouble at all; there seems to be no such formation; but if the river is open we have considerable trouble on cold mornings. At the dam, where there are three feet of flashboards supported by iron pins, the anchor ice accumulates about the pins four or five inches in height; but as soon as the sun appears it melts All along on the dam on a cold morning we notice this phenomenon. The mills are always more or less troubled at the same time with the ice collecting against the iron rakes, and they have men out there with hooks, etc., at work stirring it up so that the water can reach the wheels. I think the ice is very much as Mr. Richards describes it, sort of a "sposh." You can push a pole into it, but it is very sticky and adheres closely

Mr. Richards. There is one other circumstance which attracted my attention. I was quite sure that the ice either had formed or had been at the bottom, because it brought up stones and pieces of moss.

Mr. Coggeshall. We have observed the same thing at New Bedford, that the ice has brought up dirt from the bottom of the gatehouse.

Mr. Sparks. My company is, perhaps, a little more unfortunately situated as to anchor ice than the rest of the water companies represented here. We depend upon water principally for power to drive our pumps, and we also have an electric plant. We have 13 water-wheels. I have known within the last five years the anchor ice to accumulate on the gates so that we had to keep men hooking night and day in order to let the water through. We have 48-inch turbine wheels, running under about 11-foot head at about 100 revolutions per minute for our electric plant, and I have known the ice to churn up on those wheels so that it would resemble ice cream more than anything else, and finally stop the wheels entirely. This winter the river has been full of anchor ice for 60 miles. My pump well, that is about 15 feet long, was clogged up for a month before it thawed out. The ice accumulates outside in the river where the water doesn't run very quick, and passes down till it reaches a dam or some place where it commences to clog, and then backs up. We have trouble of this sort every year, and if the river is open we have the anchor ice just the same if the temperature is 10 degrees below zero. It is the worst stuff to contend against I know off. You can't shovel it, or do anything with it. As the gentleman says, you run a pole through it and it is hard to pull the pole out again. A few years ago I laid a water main across the river where the water was some 20 feet deep and it was full of anchor ice. I hadn't had much experience with it at that time and supposed a pipe which would weigh 100 pounds to the foot would go through it, but I found I was mistaken, and the ice had to be stirred up with poles, raised to the surface and taken off with sieve shovels before it would allow the pipe to sink. It is quite strong and will form a dam of itself. This season at our pumping station, after the wheels had been entirely stopped, we dug down close to the racks, and there was a wall of perhaps three feet of anchor ice left between them and the water, and that was absolutely tight, allowing no filtration of water at all. It was of sufficient strength so it wouldn't allow the water to break through it until it was stirred up.

Mr. Stacy. I don't know that I ever had any trouble with anchor ice in that way, but I would like to know if anybody has had pipes freeze up when the frost is coming out in the spring in a warm day and whether that has anything to do with anchor ice? I had a 6-

inch main freeze up one day when you could walk around the streets with your coat off, and the water was running and the frost coming out. I had another 4-inch main freeze up the same way. I attributed it to the radiation of the heat, a good deal on the principle of an ice cream freezer. I remember another case where they called me about 10 o'clock at night, where a service pipe had frozen in the wall. They had drawn water at 5 o'clock. It was a warm night; raining a little bit. There was a place in the wall around this pipe, where they had dug in for some reason, perhaps to thaw it out at some time. It was one of these cellar walls where the air circulates pretty freely, and the temperature had arisen enough, and there was frost enough behind to make the conditions right, and the pipe had frozen solid for about a foot. I don't suppose that is in the nature of anchor ice, and it works in just the opposite way as far as temperature is concerned.

Mr. Richards. I will say that my experience with the freezing of pipes has been exactly similar to Mr. Stacy's. At one time we were a little economical, laying our service pipes too near the surface, and a great many of them froze up, and they always froze when it was thawing above ground.

ELECTROLYSIS.

BY

John C. Haskell, Superintendent, Lynn, Mass.

[Read March 11th, 1896.

Mr. President and Members of the New England Water Works Association:—

In occupying your time for the brief period of five minutes with an experience paper I will speak upon a subject that has furnished me sufficient material for many experience papers and one which I consider to be the greatest danger that at present menaces our system of water works, namely, the electrolysis of water pipes.

It seems to me to be a danger that is ever present in all portions of our water works where electric roads are in operation, and is more dangerous from the fact that its full extent is not yet known by any one, and in some instances I meet parties that should be better informed actually believing that no danger of this description need be feared in the works under their direction.

My attention was first drawn to this subject during a conversation with the late Hiram Nevons, at that time superintendent of the water works in Cambridge, in which he stated that he had found leaks in service pipes in that city which he believed were occasioned by the action of electricity.

Previous to that time the cause of most of the small leaks in the water pipes in our city were attributed to rust. Upon learning that an hitherto unknown danger menaced our pipe system a careful examination of all supposed rust holes was made to detect the first appearance of the expected trouble. Before any undoubted damage to our pipes from this cause was found, I received additional information about this mysterious agent from a paper read before this Association, in which it was explained that the electric current used in propelling cars possessed peculiar powers, one of which was described practically as follows: That as a drop of water taken by evaporation

from the ocean into the air and driven by the winds into the most remote parts of the earth returns to the ocean, likewise all electricity generated at a power house and used as a motive power to propel cars in various directions and distances would return to the power house in which it was generated.

Always like water following the direction of least resistance or as applied to electricity the lines of greatest conductivity.

After listening to the paper and discussion that followed I began to realize more fully the danger to which we were exposed, as unfortunately the contents and metal of our water pipes furnishes a better course for the passage of the electric current than the earth in which they are situated, and I also recognized that their comparitive safety depended upon a power over which I had no control, namely, an electric railway company.

Upon interviewing the engineers of our electric road as to the probability of any danger resulting to our pipes from this direction, I was assured that no such danger existed, as they could not afford to lose the electric current and that equal facility was given to the return as to the outgoing current. Despite this assurance of safety a leak was soon found in a service pipe, evidently caused by the electric corrosion.

A portion of the pipe was taken out and the ammeter showed a large amount of electricity passing along the pipe. This amount was largely increased during the passage of cars over the spot. There also was sufficient heat in the current between the ends of the pipe to burn the hard wood handle of a screw driver. This trait, however, is more dangerous if it should develop in a building than outside in the earth, and is of more interest to the fire than the water department. The electrician of the railway company, after examining the pipes and seeing the extent of the current, admitted their responsibility in occasioning the leak and promised immediate relief, which was attempted by giving a return wire to the power house and with occasional wires at right angles across the street.

This relief proved to be insufficient, for since our first experience many others of a similar character have occurred, sufficient in number to give us some knowledge of the actual workings of the electric current in our water pipes.

I have here a diagram showing the location of a service pipe which has caused more trouble than any other in the city, having been

renewed four times within three years. The last occasion being on March 9th, 1896, after remaining in the ground thirteen months and ten days. You will observe upon inspection that the damaged portion of the pipe extended but four feet and six inches from the outer rail of the track, the remaining portion beyond the union is still in use although twenty-two years old.

The water main is situated one foot and six inches from the opposite rail and is ten inches in diameter. A service is connected to the engine house two feet from the first mentioned service pipe. This pipe is connected to the main at a point two feet and one-half distant from the outside rail of the road and has been in use twenty years without any serious deterioration. The injured pipes show the danger limit to be situated very close to the outside rail. The pipe was five feet below the surface of the street. The character of the earth is gravel. When excavating to remove the pipe on March 9th, a broken copper wire, intended originally to serve as a return wire to the power station, was found. This wire was situated one foot below the surface of the street, the extreme end being bent downwards and but two feet and seven inches distant from the pipe and without doubt hastened the destruction of the pipe.

I will also present to you a piece of lead pipe that has been in use but six months. The appearances of these pipes furnishes a better object lesson on the effect of electrolysis than any description I could give.

The principal ideas I have gathered from my experience are:

First—That there is at all portions of our city, near the lines of the electric railways, perceptible currents of electricity passing along the water pipes.

Second—That most of the pipes destroyed were within a distance of 2,500 feet from the power house, showing greater danger from the accumulative flow of the current gathered from diverging lines and finally concentrated in the single line to the power house.

Third—That the rapidity of this action is directly due to the amount of the current.

Fourth—That the greatest point of danger to service pipes laid at right angles to the track is under the rails.

Fifth—That the greater depth at which we lay the pipes ensues greater safety.

Sixth—That covering the pipes with several thicknesses of paper

and laying in a bed of cement at those points where trouble is experienced is a protection that we can furnish at small expense compared to the benefit received.

Seventh—That the switches furnish the most dangerous points, plainly allowing a greater escape of electricity than the main tracks.

Eighth—That the electric current may introduce disagreeable or dangerous qualities into the water flowing through the pipes.

We are told by experts who have made a study of the electrolytic subject, that a current passing along a pipe upon meeting a poor joint divides, a part going outside and part inside, and that besides the injury from corrosion great danger exists from salts of iron and salts of lead formed by the electrolytic action, also that the passage of the electric current through the water inside the pipe will destroy all animal and vegetable organisms contained therein, thus furnishing another danger in the nature of impure water, both in taste and odor. Although our first knowledge of this subject seemed enveloped in mystery, enough facts have been discovered to show its dangerous character and the importance of removing it entirely.

Experts agree that a storage battery system would be entirely harmless. This solution, however, cannot be attained until more practical results are shown than can be at the present time.

While there is yet much to be learned in the construction and operation of trolly roads, I have no doubt but that with the joints of the rails well bonded together to prevent the escape of the electric current and a return wire of sufficient capacity to convey the full current back to the power station no serious damage would be caused until the good character of the first construction is impaired.

This latter contingency is ever present and is the most difficult feature to control as the impaired work would, to a large extent, be hidden from inspection under the ground. To ensure comparative safety for our water pipes concerted action should be taken to secure such legislative restrictions as might be deemed the best adapted to prohibit electric roads from permitting the escape of the electric current into our streets.

DISCUSSION.

Mr. Hodgson. I would like to inquire whether when the lightning strikes the pipes if the cement doesn't prevent it from passing off into the ground without bursting the pipe?

Mr. Haskell. We have had more experience of that kind than I wish we had. We had a case a few years ago where we supposed there were a couple of bursts. We repaired them and turned the water on and discovered there were others, and the next day we relaid the entire street and found 22 bursts within a distance of 300 feet.

Mr. Holden. Have you ever measured the amount of the return current on the pipes with a volt meter?

Mr. Haskell. Yes, sir, I have. I don't know as I care to talk about that, because I am not an electrician, and I have to depend on certain machines with which I am not as conversant as I might be. But on the very first occasion, and I remember that perhaps better than I do the more recent ones, because there have been so many, there were 30 amperes. That was taken by an electrician, not by myself. It was largely increased, almost doubled, on the passage of the cars. There have been even larger amounts than that measured; and while I could get notes that tell the difference in the amounts, I think that is enough, because what we are interested in is the fact that it destroys our pipes, even in small amounts.

Mr. Holden. Where do you make your connection to your pipe in measuring the return?

Mr. Haskell. Sometimes when I am doing it for curiosity I go to a hydrant, but when I have a piece of water pipe eaten out there is a section of it cut out that we have to put in again, and I make the connection right between the two ends, right in the place that is gone, and I suppose that gives as good chance to measure it as any, and comes pretty near showing the actual amount of the current, does it not? I ask the question of any electrician who may be here.

Mr. Holden. I asked because I have experimented a little on our works, and have made connections between the track and the hydrant, and I have never been able to find any current at all, and it was a question with me whether there wouldn't be some way of finding the current if I were to connect directly with the pipe instead of with the hydrant.

Mr. Haskell. Our works were about the first electric works which were ever put in operation. It was a good while before we really found the bad work in our pipe. As I have said in the paper, if an electric road is properly built, if they have good continuous bonds between the rails, that stops the escape of electricity. As I understand it, the electricity is generated in the power station and

is carried out on the trolley wire. The wheel follows along on that trolley wire and takes up electricity, which is then carried through certain parts of the car until it finally reaches the rheostat. When it arrives at the rheostat it has got to a place that perhaps would be more familiarly known to us as the throttle valve on an engine, and it is ready then, to go to work. The electricity goes into the wheels of the car, and it touches the rails, and everything goes smoothly until it comes to a broken connection. When there is any trouble in a joint, or a break, there will be a spark of fire, you can see it go clear across the street. That is an escape of electricity you notice. If it isn't quite as bad it goes into the ground and you don't see it. But all the electricity that escapes is the electricity which gives us trouble. If they have got a good return wire it gets back into that return wire and does not reach our water pipes, but otherwise it is likely to get into them and that is where the trouble is.

Mr. Cook. I would like to ask who pays for the renewals, the city or the street railway?

Mr. Haskell. We have paid so far, under certain promises to give us better work. Now, I am not going to find any fault with our railroad people in Lynn, because I recognize the fact that they have done a good deal to try to give us good work, and more than that, we expect to get paid for the expense they have caused. We have had a good many renewals, but have not yet brought it to a head to get the money for it. It is a hard thing to get money out of a railroad company until you have proved that they have got to pay it. It really means a law suit in which you don't exactly know where you are going to come out. And I think action to insure getting the work done in a proper manner in the first place is the vital point in the handling of electricity. The question is not to handle it after it has got into the ground, but to keep it out; that is the important point. I am satisfied now that there isn't a necessity for trouble everywhere, as I thought there was when I first heard this matter discussed. The only point is not to let it get away from the rails at all, but if it does, then we want to catch it just as soon as we can, before it gets to the water pipes, and give it a safe course back.

Mr. Coffin. I would like to ask Mr. Haskell if he has found it to be a fact that the trouble is largely located within a short distance from the power station?

Mr. Haskell. No, sir. As I stated, we find electricity all over the whole line of our water pipes where they are in close vicinity to the electric tracks. Over two miles from our station we had a leak from this cause. In this case the electric road made objections to paying the meter bill. There was a 2-inch supply went into their car-house and it was in low ground where there was a nice opportunity for the water to escape after it passed the meter, and we hadn't discovered that there was a leak beyond the meter before a large amount of water went through. When discovered, we took it out, and that is one of the bills the company did pay, both for putting back the pipe and the extra water which was used. I was a little sorry about that, because I don't like to charge anybody for water from which they don't get any benefit. That was over two miles away from the station. If there is imperfect construction anywhere, I don't care if it is ten miles away, you will have trouble. I don't think distance will save you. For instance, if there is a switch located ten miles away from a power station and there is a break in the joint there, I don't see why they wont lose just as much electricity as they would if the break was near the power station, only you haven't got the accumulated flow of electricity. A small amount, we will say three amperes, might pass through a pipe a long time and not seriously affect it. Comparing the energy to that of water, which we are more familiar with, you see a little bit of water flowing in the gutter up at the top of a steep hill in a hard shower, and it doesn't do any damage there; but as it comes down a little ways it increases in volume and by and by it does do serious damage. Electricity, I take it, is practically similar. When we are way off at the extreme end of the electric line the amount of liberated electricity is very slight; but as we come nearer the station the current from the various lines concentrates until it is sufficient to do serious damage.

Mr. Coffin. My knowledge on electrical matters is somewhat limited; but I have understood from my study of the matter that the danger was confined to within a comparatively short distance from the power station, when the current was run, as they call it, positive to the trolley; and if the current was run negative to the trolley, the dangerous district would be on the outside. That is to say, where the trolley wire is positive the danger district covers an area perhaps of from half to three-quarters of a mile in radius

from the power station, and the danger then is when the current leaves the pipe to go through the ground to the power-house. It is where the current leaves the pipe and goes into the ground, where there is a difference in potential, or, as we would call it in water works language, a difference in pressure, that the danger occurs, and at no other place. Where the current goes from the railroad track, or from the ground into the pipe, there is no danger.

MR. HASKELL. I don't think that can be considered to be the case, because our experience shows there is trouble over two miles away. We did have serious difficulty at one time near the power-house, but that has been entirely remedied and we haven't had the least trouble there for more than a year.

MR. COFFIN. Did you make connections between the return wires and your pipes?

MR. HASKELL. They increased the size of the return wires and they ran more or less lines across the street, as they said, to catch the electricity.

MR. COFFIN. And made connections with your pipe?

MR. HASKELL. No, sir; they didn't connect with the pipes. While some electricians say connections should be made, the electrician of the Lynn company said that wouldn't be the proper thing, and as long as they were doing the work of course I didn't undertake to interfere with them. I think the only truth in the statement that the danger is confined within an area a short distance from the power-house, is that the danger is greater near there than elsewhere; but there is danger at any point on an electric road where the work is imperfect. If there is poor work there will be trouble with the water pipes even ten miles away.

MR. COFFIN. Perhaps I made my statement a little too strong when I said that all the danger was confined to this small district. That is not what the electricians say; but that the greater proportion of the danger is there, and that the danger outside of this district is small.

MR. NELSON. My experience in laying gas pipes in Boston has been something similar to that which Mr. Haskell has had with his water pipes. I put in a pipe in Harrison avenue, something over two years ago, and in less than two years the entire pipe was eaten up. In regard to Mr. Coffin's statement as to the trouble being confined to the vicinity of the power station, I know of a case

in Boston where a 12-inch gas pipe out on Blue Hill avenue, in Dorchester, four miles away from the station, was destroyed. That was a very peculiar case, in that there was a hole eaten in the pipe about as big as a man's fist, and we cut a piece of pipe and put a new piece in and haven't had any trouble since; that was about a year ago. Down on the corner of Dover and Albany street I cut a 12-inch gas main one day to put a T in, and in doing that we didn't shut the gas off but bagged it on each side, and when we were putting in the T, as soon as the two pieces of pipe touched, the sparks came out of the iron and set the whole thing afire, and we had to call out the fire department.

PROCEEDINGS.

ADJOURNED MEETING.

YOUNG'S HOTEL, BOSTON, MASS., Feb. 12th, 1896.

President FitzGerald in the chair; members and guests were present as follows:

ACTIVE.

Abbott, E. L., Boston, Mass.
Bancroft, L. M., Reading, Mass.
Barbour, F. A., Brockton, Mass.
Batchelder, G. E., Worcester, Mass.
Beals, J. E., Middleboro, Mass.
Bigelow, J. F., Marlboro, Mass.
Bowers, Geo., Lowell, Mass.
Brackett, Dexter, Boston, Mass.
Chace, Geo. F., Taunton, Mass.
Chadbourne, E. J., Wakefield, Mass.
Chandler, C. E., Norwich, Conn.
Chase, John C., Wilmington, N. C.
Clark, H. W., Lawrence, Mass.
Coffin, F. C., Boston, Mass.
Coggeshall, R. C. P., New Bedford, Mass.
Conant, H. W., Gardner, Mass.
Cook, Byron I., Woonsocket, R. I.
Cushing, Lucas, Boston, Mass.
Ellis, John W., Woonsocket, R. I.
Evans, Geo. E., Boston, Mass.
Felton, B. R., Boston, Mass.
FitzGerald, Desmond, Brookline, Mass.
Forbes, F. F., Brookline, Mass.
Forbes, Z. R., Brookline, Mass.
Flinn, R. J., Brookline, Mass.
Fuller, Frank L., Boston, Mass.
Gleason, F. B., Marlboro, Mass.
Gould, J. A., Boston, Mass.
Hale, Richard A., Lawrence, Mass.
Hammatt, E. A. W., Boston, Mass.
Harrington, G. W., Wakefield, Mass.
Hartwell, David A., Fitchburg, Mass.
Haskell, John C., Lynn, Mass.
Hastings, V. C., Concord, N. H.
Hawes, Louis, Boston, Mass.
Hazen, Allen, Boston, Mass.
Hodgdon, F. W., Arlington, Mass.
Holden, H. G., Nashua, N. H.
Hyde, H. N., Newton, Mass.
Jackson, D. D., Newtonville, Mass.
Jenkins, G. S., Lawrence, Mass.
Kent, Willard, Narragansett Pier, R. I.
Kieran, Patrick, Fall River, Mass.
Kimball, G. A., Boston, Mass.
Knowles, Morris, Boston, Mass.
Locke, J. W., Brockton, Mass.
McNally, Wm., Marlboro, Mass.
Nash, H. A., Boston, Mass.
Neubling, E. L., Reading, Pa.
Patch, W. W., Fayville, Mass.
Rice, G. S., Boston, Mass.
Richards, W. H., New London, Ct.
Rogers, H. W., Haverhill, Mass.
Russell, Daniel, Everett, Mass.
Salisbury, A. H., Lawrence, Mass.
Shepard, F. J., Derry, N. H.
Shirreffs, Reuben, Richmond, Va.
Stanwood, J. H., Boston, Mass.
Stearns, F. P., Boston, Mass.
Taylor, F. L., Brookline, Mass.
Thomas, R. J., Lowell, Mass.
Thomas, W. M., Hingham, Mass.
Tower, D. N., Cohassett, Mass.
Vaughn, W. H., Wellesley Hills, Mass.
Walker, C. K., Manchester, N. H.
Wallace, E. L., Franklin Falls, N. H.
Welch, J. A., Methuen, Mass.
Whipple, Geo. C., Brighton, Mass.
Whitney, J. C., West Newton, Mass.
Winship, Horace B., Norwich, Conn.
Winslow, Geo. E., Waltham, Mass.
Wiswall, E. T., West Newton, Mass.

ASSOCIATE.

H. R. Worthington, by James M. Betton.
Builders Iron Foundry, by T. C. Clifford.
Chadwick Lead Works, by A. H. Brodrick.
Chapman Valve Co., by E. L. Ross.
Deane Steam Pump Co., by Chas. P. Deane.
Gilchrist & Taylor, by H. N. Libbey.
The Goulds Manufacturing Co., by Mr. Mackie.
Hersey Manufacturing Co., by Samuel Harrison.
The Hydraulic Construction Co., by Wm. D'H. Washington.
Ludlow Manufacturing Co., by Mr. Gould.
National Meter Co., by Mr. Lufkin.
Neptune Meter Co., by W. G. Zick.
Perrin Seamans & Co., by Mr. Bond.
Thomson Meter Co., by E. L. Abbott.
Union Water Meter Co., by J. P. K. Otis.
Walworth Manufacturing Co., by C. H. Polsey.

HONORARY.

The Engineering Record, by C. J. Underwood, Jr.

GUESTS.

Bartlett, R. S.
Crafts, A. N.
Crawford, J. W., Clerk of Water Board, Lowell, Mass.
Crowley, T. M.
Fairbank, John H., Chairman Water Board, Winchendon, Mass.
Felix, Geo. H., President Water Board, Reading, Pa.
Gould, H. F.
Marble, W. F.
Rogers, H. T.
Thomas, H. L.

ELECTION OF MEMBERS.

George S. Jenkins, Mayor and member of the Water Board, Lawrence; Arthur D. Marble, City Engineer, Lawrence; Frank Kimball, Civil Engineer, Boston; Gerald M. Bliss, Civil Engineer, Walpole, Mass., were elected resident members; Emil L. Neubling, Engineer and Superintendent of the Reading, Pennsylvania, Water Works, was elected a non-resident member.

Papers were read by Mr. George Bowers, City Engineer, Lowell, on the "Description of the Second Tube Well Plant at Lowell, Mass.;" George F. Chace, on "Handling Fires While Changing Distributing Mains Upon Important Streets;" Freeman C. Coffin, C. E., of Boston, on "The Friction in a Few Pumping Mains at Various Velocities;" R. A. Hale, C. E., Assistant Engineer of Essex Company,

Lawrence, on "Some Notes of the Formation of Tubercles on the Inner Surface of Penstocks;" and F. F. Forbes, C. E., Superintendent, Brookline, Mass., on "The Appearance of Chara Fragilis in a Reservoir of a Public Water Supply."

Mr. Jackson, at the request of Prof. Sedgwick, showed a photograph, taken by the Roentgen process, of a human hand, showing the skeleton and the exact shape of each bone and the outline of the hand.

QUARTERLY MEETING.

YOUNG'S HOTEL, BOSTON, March 11th, 1896.

The following members and guests were present:

ACTIVE.

Abbott, E. L., Boston, Mass.
Babbidge, P. F., Keene, N. H.
Baldwin, C. H., Boston, Mass.
Bancroft, Lewis M., Reading, Mass.
Batchelder, G. E., Worcester, Mass.
Beals, J. E., Middleboro, Mass.
Bigelow, J. F., Marlboro, Mass.
Bowers, George, Lowell, Mass.
Brown, J. H., Boston, Mass.
Chace, G. F., Taunton, Mass.
Chase, J. C., Wilmington, N. C.
Coffin, F. C., Boston, Mass.
Coggeshall, R. C. P., New Bedford, Mass.
Cook, B. I., Woonsocket, R. I.
Doane, A. O., Newton, Mass.
Ellis, J. W., Woonsocket, R. I.
Forbes, F. F., Brookline, Mass.
Fuller, F. L., Boston, Mass.
Gleason, F. B., Marlboro, Mass.
Glover, A. S., Boston, Mass.
Gould, A. A., Leicester, Mass.
Gould, J. A., Boston, Mass.
Gow, F. W., Medford, Mass.
Gowing, E. H., Boston, Mass.
Hale, R. A., Lawrence, Mass.
Harrington, G. W., Wakefield, Mass.
Haskell, J. C., Lynn, Mass.
Hastings, V. C., Concord, N. H.
Hazard, T. G., Jr., Narragansett Pier, R. I.
Hodgdon, F. W. Arlington, Mass.
Holden, H. G., Nashua, N. H.
Jackson, D. D., Newtonville, Mass.
Johnson, W. S., Brooklyn, N. Y.
Kent, E. W., Woonsocket, R. I.
Kent, W., Narragansett Pier, R. I.
Kieran, Patrick, Fall River, Mass.
Kimball, G. A., Boston, Mass.
Kingman, Horace, Brockton, Mass.
Knowles, Morris, Lawrence, Mass.
Locke, Jas. W., Lawrence, Mass.
Luther, W. J., Attleboro, Mass.
McNally, Wm., Marlboro, Mass.
Northrop, F. L., Milford, Mass.
Noyes, A. F., Boston, Mass.
Perry, F. G., Pawtucket, R. I.
Porter, Dwight, Boston, Mass.
Richards, W. H., New London, Ct.
Shippee, J. D., Holliston, Mass.
Sparks, H. T., Bangor, Me.
Taylor, F. L., Brookline, Mass.
Taylor, L. A., Boston, Mass.
Thomas, R. J., Lowell, Mass.
Thomas, W. H., Hingham, Mass.
Tower, D. N., Cohasset, Mass.
Vaughn, W. H., Wellesley Hills, Mass.
Welch, J. A., Methuen, Mass.
Whitney, J. C., West Newton, Mass.
Winslow, F. I., Boston, Mass.
Winslow, G. E., Waltham, Mass.

ASSOCIATE.

Chapman Valve Manufacturing Co., by E. L. Ross.
Crosby Steam Gage and Valve Co., by Robert Pirie.
Deane Steam Pump Co., by C. H. Hayes.
Hersey Manufacturing Co., by Samuel Harrison.
Gould Manufacturing Co., by Mr. Mackie.
Ludlow Valve Manufacturing Co., by H. B. Winship.
McNeal Pipe and Foundry Co., by Wilmer Reed.
Perrin, Seamans & Co., by L. Bond.
Smith, Anthony P., by W. H. Van Winkle.
Thomson Meter Co., by A. H. Higley.
Walworth Manufacturing Co., by C. H. Polsey.
Wood, Lester E.
Worthington, H. R., by E. H. Foster and J. M. Betton.

GUESTS.

Mayor Beason, Lynn, Mass.
Messrs. Putnam, Jones, Hills, Weaver, and Crawford, Water Commissioners, Lowell, Mass.
J. M. Nelson, Boston, Mass.

Vice President Beals, after lunch had been served, called the meeting to order and said:

I don't know but I ought to apologize for being in the chair to-day, but perhaps necessity needs no apology. The ranking officers are absent, and I will do the best I can in the position in which I now find myself. The secretary has some business to bring before the Association.

The secretary read the names of the following applicants for membership:

ELECTION OF MEMBERS.

Resident Active—Amos Gould, water commissioner, Leicester, Mass.; Andrew Holden, water commissioner, Fall River, Mass.; J. H. Fairbank, water commissioner, Winchendon, Mass.; Arthur N. Cram, water commissioner, Walpole, Mass.

Non-Resident Active—Fred J. Gubelman, assistant engineer, East Jersey Water Co., Jersey City; Louis L. Tribus, hydraulic and sanitary engineer, 80 Warren street, New York.

On motion of Mr. Coggeshall the secretary was directed to cast the vote of the Association for the above named candidates, and having done so they were declared elected.

The secretary read a communication from the associate members announcing that they had selected Mr. Henry F. Jenks, of Paw-

tucket, R. I., to have charge of the exhibits at the next annual convention, to be holden in Lynn, in June.

On motion of Mr. Stacy the president was directed to appoint a committee of five to nominate officers for the ensuing year. It was announced that the committee would be appointed later.

The presiding officer then presented His Honor, Mayor Bessom, of Lynn, who spoke as follows:

Mr. Chairman, when I received an invitation from our superintendent of water works to be with you this afternoon I did not suppose I was to be called upon for a speech. I imagined that my pleasant duty would be to listen, perhaps, to a dissertation in regard to the animalculæ or some of the creatures with unpronounceable names which are in the habit of infesting our waters; and it is a little embarrassing for me to stand here and attempt to talk to gentlemen in regard to a matter with which they are much more familiar than I—not but what I use water upon certain occasions. But in regard to the quality, and in regard to the methods of procuring and distributing water, and the precaution that advanced civilization demands should be taken toward the purification of our drinking waters, I think I may safely say you are much more familiar with them than I. What I have had to do in my official capacity, serving upon the water committee of the legislature for two years, has looked more to quantity, perhaps, than to quality of water. We endeavored, so far as we could, when we had petitions before our committee, to use the parties who came to us with their applications in a fair manner. Where two towns came in and claimed the same source of supply, we endeavored, so far as we could, to discover who had the best right, and while, perhaps, our judgment and decision did not always satisfy everybody, we certainly in most instances satisfied one of the parties, and that was doing pretty well.

The water question is a question which is engrossing the attention of the people of our Commonwealth more and more every year. In considering this matter in a legislative way it was sometimes difficult to determine where the demand for water would end. We often came across this difficult problem to solve. Communities would come in and ask for a source of supply, and we would find that in order to give them what they asked for we in some cases would have absolutely to wipe out of existence some of the best

property in the State. It was a serious question whether we should destroy valuable mill property in order to give people what they ought to have to drink. When you take away water that is used for power, that is something that can be compensated for to a certain extent. But many of these large mill corporations need to use the water for washing purposes in the manufacture of their woolen goods; and it was a very serious question and it often made me think that if the thing kept on many of our valuable mill properties would be entirely destroyed. Of course it was always provided that the community taking water should make compensation to the owners, and oftentimes, I have no doubt, when the owners received the compensation, they got all that they were entitled to; but having received that compensation there was then nothing to prevent them from folding their tents and silently stealing away, and the community which had had the benefit of a large manufacturing industry might be deprived of it. That is one of the things that made us stop and consider where this demand for water supply was tending. Of course the first thing for consideration is that the people shall have water; an abundance of water of good quality; the very purest and best water possible to obtain; that is certainly the first consideration, and we did give them all that we could in that way. But there is this other thing to take into consideration, and I think it is something that should engage our attention.

I was therefore glad when this grand scheme, this scheme of large proportions, the Metropolitan Water Supply, was talked of, because it seemed to me that might possibly eliminate this great problem we have to consider. As I understand the Metropolitan Water Supply is to be taken from the hill towns, from a country that is sparsely inhabited, where there are fewer of these valuable mill rights than there are in many sections, and a country which is amply able to supply a large amount of water sufficient to meet the needs for a very long time. I think the estimate is, when the upper and lower Ware and the Swift river watersheds are developed, the supply will be sufficient for a population of 5,000,000 of people.

Now, Mr. Chairman, I beg your pardon for taking up so much of your time, for I feel as though I were intruding upon the business which has called you together this afternoon.

The regular program for the afternoon was then proceeded with. Fred. G. Perry, Assistant Commissioner of Public Works, Paw-

tucket, R. I., read a paper on "Pressure Recording Gauges." The subject was discussed by Mr. Whitney, Mr. Haskell, Mr. Fuller, Mr. Holden, Mr. Richards and Mr. Chase. Frank L. Northrop gave a description of the Filtering Gallery of the Milford Water Works, and answered questions which were asked by Mr. Chace, Mr. Haskell, Mr. Thomas and Mr. Fuller. Mr. Coggeshall presented a paper entitled "An Experience with Anchor Ice." Mr. Richards, Mr. Hale, Mr. Sparks and Mr. Stacy also gave experiences. Mr. Haskell, of Lynn, read the closing paper, his subject being "Electrolysis," and the subject was further discussed by Mr. Holden, Mr. Coffin and others.

New England Water Works Association Membership Roll.

JUNE 1, 1896.

NOTE.—The Secretary requests to be advised of existing errors or change of address from that which appears in the following list.

ACTIVE MEMBERS—RESIDENT AND NON-RESIDENT.

Abbott, Everett L.
"The Varrick," Kent street, Brookline, Mass.

Allen, Charles A.
Civil Engineer, 44 Front street, Rooms 109 and 110, Worcester, Mass.

Allen, Charles F.
Treasurer, Hyde Park, Mass.

Allis, Solon M.
Civil Engineer, Madison, N. J.

Amerman, Lemuel.
Manager Water Works, Coal Exchange, Scranton, Pa.

Andrews, Frank A.
Assistant Superintendent, Nashua, N. H.

Armstrong, S. G.
First Assistant Public Works Office, Pittsfield, Mass.

Ashwell, Wm. H.
Civil Engineer, 76 Home Bank Building, Detroit, Mich.

Babbidge, P. F.
Superintendent, Keene, N. H.

Babcock, Stephen E.
Chief Engineer, Little Falls, N. Y.

Bacot, R. C., Jr.
Superintendent Meter Department, P. O. Box 461 Port Chester, N. Y.

Bagnell, Richard W.
Superintendent, Plymouth, Mass.

Bailey, E. W.
City Engineer, Somerville, Mass.

Bailey, George I.
Superintendent, 61 State street, Albany, N. Y.

Baldwin, Charles H.
Box 2410, or 159 Franklin street, Boston, Mass.

Baldwin, Richard.
Proprietor Water Works, Terryville, Conn.

Bancroft, Arthur G.
Civil Engineer, Box 506, Reading, Mass.

Bancroft, Lewis M.
Superintendent, Reading, Mass.

Barbour, Frank A.
Civil Engineer, P. O. Box 1235, Brockton, Mass.

Barns, Everett.
Superintendent, Westerly, R. I.

Barrett, Albert P.
Water Registrar, Woburn, Mass.

Barrus, George H.
Consulting Steam Engineer, 95 Milk street, Boston, Mass.

Bartlett, Charles H.
Civil Engineer, 852 Elm street, Manchester, N. H.

Bassett, Carroll, Ph.
Civil Engineer, Summit, N. J.

Batchelder, George E.
Registrar, Worcester, Mass.

Batcheller, Francis.
Commissioner, North Brookfield, Mass.

Bates, Oren B.
Superintendent, Clinton, Mass.

Bates, Theodore C.

Chairman Water Commissioners, North Brookfield. Address, 29 Harvard street, Worcester, Mass.

Battles, James M.

120 Marginal, cor. Cottage street, East Boston, Mass.

Beals, Joseph E.

Superintendent, Middleboro, Mass.

Beasom, C. B.

Civil Engineer, 71 Wall street, New York city.

Benzenberg, G. H.

City Engineer, Milwaukee, Wis.

Berkey, John A.

Pres. Electric and Water Co., Little Falls, Minn.

Bickford, Nathan B.

61 Minot street, Neponset, Mass.

Bigelow, James F.

City Engineer, Marlboro, Mass.

Billings, William R.

15 Harrison street, Taunton, Mass.

Birkinbine, Harry.

Civil Engineer, Wayne, Delaware County, Penn.

Bisbee, Forrest E.

Superintendent, Auburn, Me.

Bishop, George H.

Civil Engineer, Middletown, Conn.

Bishop, Watson L.

Superintendent, Dartmouth, N. S.

Bliss, Gerald M.

Engineer Water Department, Walpole, Mass.

Blossom, William L.

Civil Engineer, 355 Washington street, Brookline, Mass.

Boggs, Edward M.

Professor of Civil and Hydraulic Engineering, University of Arizona, Tucson, Arizona.

Bolling, Charles E.

Superintendent, Richmond, Va.

Bowers, George.

City Engineer, Lowell, Mass.

Brackett, Dexter.

Engineer Distribution Dept., Metropolitan Water Board, 3 Mt. Vernon street, Boston, Mass.

Bradley, R. H.

Receiver, Marshall and Burdick, Contracting Engineers, Watertown, South Dakota.

Brinsmade, Daniel S.

Engineer and Agent Ousatonic Water Co., Birmingham, Conn.

Broatch, J. C.

Superintendent, Middletown, Conn.

Brown, Arthur W. F.

Registrar, Fitchburg, Mass.

Brown, Edward H.

Superintendent and Treasurer Nevada County, N. G. R. R., Grass Valley, Cal.

Brown, J. Henry.

3 Tremont street, Charlestown, Boston, Mass.

Brown, Milton A.

Superintendent, Perth Amboy, N. J.

Brownell, Ernest H.

174 Weybosset street, Providence, R. I.

Brush, Charles B.

Civil Engineer, 1 Newark street, Hoboken, N. J.

Bucknam, Geo. A. P.

Superintendent, Norwood, Mass.

Burke, James E.

Superintendent, Princeton Water Co., Princeton, N. J.

Burleigh, John M.

Superintendent, South Berwick, Maine.

Burley, Harry B.

31 Milk street, Room 55, Boston, Mass.

Burnham, Albert S.

Superintendent, Revere, Mass.

Burnie, James.

Superintendent, Biddeford, Me.

Burr, William H.

Professor of Civil Engineering, Columbia College, and Consulting Engineer, New York city.

Bush, Edward W.
Box 1006, Middletown, Conn.

Butler, J. Allen.
Superintendent, Portland, Conn.

Cairns, R. A.
City Engineer, Waterbury, Conn.

Card, Huber D.
City Engineer, Willimantic, Conn.

Carroll, Fred. B.
8 Dexter street, Woonsocket, R. I.

Cavanagh, John T.
Water Commissioner, Quincy, Mass.

Chace, George F.
Superintendent, Taunton, Mass.

Chadbourne, E. J.
Superintendent, Wakefield, Mass.

Chandler, Charles E.
City Engineer, 161 Main street, Norwich, Conn.

Chandler, Charles F.
Professor of Chemistry, School of Mines, Columbia College, New York City.

Chandler, Henry.
Water Comissioner, Manchester, N. H.

Chase, John C.
Superintendent, Wilmington, N. C.

Childs, Wm. H.
226 Clinton avenue, Brooklyn, N. Y.

Clapton, Wm. F.
Superintendent, Newtown, N. Y.

Clark, D. W.
President Water Company, Portland, Me.

Clark, Ezra.
President and Superintendent, Hartford, Conn.

Clark, Frederick W.
Clerk, Chestnut Hill Reservoir, Boston, W. W., Brighton, Mass.

Clark, Harry W.
State Experiment Station, Lawrence, Mass.

Clarke, E. W.
95 Milk street, Room 54, Boston, Mass.

Cleaveland, W. F.
Brockton, Mass.

Cochran, Robert L.
Superintendent, Nahant, Mass.

Codd, William F.
Superintendent, Nantucket, Mass.

Coffin, Freeman, C.
Civil and Hydraulic Engineer, 53 State street, Boston, Mass.

Coggeshall, R. C. P.
Superintendent, New Bedford, Mass.

Colby, H. L.
Civil Engineer, Salem, Mass.

Collins, Lewis P.
Water Commissioner, Lawrence, Mass.

Conant, H. W.
Superintendent, Gardner, Mass.

Conant, Whitney.
Secretary Water Co., Long Branch, N. J.

Congdon, John L.
East Greenwich, R. I.

Connell, Michael A.
Superintendent, St. Hyacinthe, P. Q.

Cook, Byron I.
Superintendent, Woonsocket, R. I.

Cook, Henry A.
Superintendent, Salem, Mass.

Crandall, F. H.
Superintendent and Treasurer, Burlington, Vt.

Crandall, George K.
Civil Engineer, New London, Conn.

Crilly, P. F.
Superintendent, Woburn, Mass.

Croes, J. J. R.
Civil Engineer, 68 Broad street, Morris Building, New York city.

Crowell, George E.
President Water Works, Brattleboro, Vt.

Cushing, Lucas.
Box 108, Mansfield, Mass.

Daboll, L. E.
Civil Engineer, New London, Conn.

Darling, Edwin.
Pawtucket, R. I.

Davis, F. A. W.
Vice-President and Treasurer Water Co., Indianapolis, Ind.

Davis, J. M.
Superintendent, Rutland, Vt.

Davis, William E.
Superintendent, Sherburne, N. Y.

Davison, George S.
Civil Engineer, Pittsburgh, Penn.

Dawson, Alex. S.
Eng. Department Metropolitan Water Board, 3 Mt. Vernon street, Boston, Mass.

Dean, Francis W.
Mechanical Engineer, Exchange Building, 53 State street, Boston, Mass.

Dean, Seth.
Civil Engineer, Glenwood, Iowa.

Decker, J. H.
Room 37, Municipal Building, Brooklyn, N. Y.

Delisle, J. Olivier.
Civil Engineer, 443 Dorchester street, Montreal, P. Q.

Denman, A. N.
Secretary and Manager, Des Moines, Iowa.

Dennett, Nathaniel.
Superintendent, Somerville, Mass.

Denton, J. E.
Professor of Experimental Mechanics, Stevens Institute, Hoboken, N. J.

Devlin, George A.
Asst. Engineer Boston Water Works, Marlborough, Mass.

Diven, J. M.
Superintendent Water Co., Elmira, N. Y.

Doane, A. O.
Eng. Department, Metropolitan Water Board, 3 Mt. Vernon street, Boston, Mass.

Dolan, Edward.
Superintendent, Troy, N. Y.

Doran, Hugh F.
Superintendent, Port Huron, Mich.

Dotten, William T.
Superintendent, Winchester, Mass.

Drake, Albert B.
Civil Engineer, 164 William street, New Bedford, Mass.

Drake, B. Frank.
Water Commissioner, Lakeport, N. H.

Drake, Charles E.
Civil Engineer, New Bedford, Mass.

Drown, Thomas M.
President Lehigh University, South Bethlehem, Pa.

Dunbar, E. L.
Superintendent, Bay City, Mich.

Dyer, Eben R.
Superintendent Distribution, Portland, Me.

Eardley, B. A.
Superintendent Pacific Improvement Co. Water Works, Pacific Grove, Monterey Co., Cal.

Eastman, Henry E.
Superintendent, Westport, N. Y.

Eddy Chas. E.
President Water Co., Plattsmouth, Neb.

Eddy, Harrison P.
Supt. Sewer Department, City Hall, Worcester, Mass.

Ellis, George A.
Civil Engineer, 158 Sherman street, Springfield, Mass.

Ellis, John W.
Civil Engineer, Woonsocket, R. I.

Ellison, W. P.
President Water Board, Newton, Mass.

Ervin, John.

Secretary and Treasurer Middleton Water Supply Co., Bridgetown, N. S.

Evans, George E.

Civil Engineer, 95 Milk street, Boston, Mass.

Fales, Frank L.

Eng. Dept. Metro. Water Board, 3 Mt. Vernon street, Boston, Mass.

Fanning, John T.

Consulting Engineer, Kasota Block, Minneapolis, Minn.

Farnham, Elmer E.

Superintendent, Box 109, Sharon, Mass.

Farnum, Loring N.

Hydraulic Engineer, 53 State street, Boston, Mass.

Felton, B. R.

Civil Engineer, 10 Tremont street, Boston, Mass.

Felton, Charles R.

Asst. Engineer Sewerage Commissioners' Office, Brockton, Mass.

Fifield, John W. D.

Water Commissioner, North Brookfield, Mass.

Fish, J. B.

Superintendent, Scranton, Pa.

Fiske, Wilbur D.

Water Commissioner, Melrose, Mass. Address, 48 Arch street, Boston, Mass.

FitzGerald, Desmond.

Superintendent Western Division and Resident Engineer Additional Supply Boston Water Works, Brookline, Mass.

Flinn, Richard J.

Pumping Engineer, Brookline, Mass.

Fobes, A. A.

Engineer Board of Public Works, Pittsfield, Mass.

Folwell, A. Prescott.

Civil Engineer, 1224 Betz Building, Philadelphia, Penn.

Forbes, F. F.

Superintendent, Brookline, Mass.

Forbes, Murray.

Manager Westmoreland Water Co., Greensburgh, Penn.

Forbes, Z. R.

Water Registrar, Brookline, Mass.

Foss, William E.

Engineers' Dept. Metro. Water Board, 3 Mt. Vernon street, Boston, Mass.

Foster, Joel.

Superintendent, Montpelier, Vt.

Foye, Andrew E.

Civil Engineer, 41 East 49th street, New York city.

Freeman, John R.

Hydraulic Engineer, 31 Milk street, Room 55, Boston, Mass.

French, D. W.

Deputy Superintendent Hackensack Water Company, No. 1 Newark street, Hoboken, N. J.

Fteley, Alphonse.

Chief Engineer, Aqueduct Commissioners, 213 Stewart Building, New York city.

Fuller, Frank L.

Civil Engineer, 12 Pearl street, Room 35, Boston, Mass,

Fuller, Geo. W.

Civil Engineer, Box 614, Louisville, Ky.

Gamwell, J. H.

Treasurer Water Company, Palmer, Mass.

Gardner, L. H.

Superintendent Water Works Company, New Orleans, La

Gerhard, William Paul.

Civil Engineer, Consulting Engineer for Sanitary Works. 36 Union Square, East, New York city.

Gerrish, William B.

Superintendent and Engineer, Oberlin, Ohio.

Gerry, L. L.

Civil Engineer, Room 1, Chase's Block, Stoneham, Mass.

Gilbert, Julius C.

Superintendent, Whitman, Mass.

Gilderson, D. H.

Superintendent, Bradford, Mass.

Gleason, Fred B.
Inspector, Marlboro, Mass.

Gleason, T. C.
Superintendent, Ware, Mass.

Glover, Albert S.
Trèmont Temple Bldg, Boston, Mass.

Goodier, Andrew B.
Treasurer and Superintendent, Southbridge, Mass.

Goldthwait, W. J.
Marblehead, Mass.

Goodnough, X. H.
Engineer, State Board of Health, Room 140 State House, Boston, Mass.

Goodwin, John A.
Box 439, Madison, Me.

Gould, J. A.
Constructing Engineer, Brookline Gas Lt. Co., 153 Tremont street, Boston, Mass.

Gow, Frederick W.
Superintendent, Medford, Mass.

Gowing, E. H.
95 Milk street, Boston, Mass.

Graham, James W.
Superintendent Meter Dept., Portland, Maine.

Greene, S. C.
Chairman Water Board, St. Albans, Vt.

Gregg, Herman.
Civil Engineer, Box 325, Waverley, Mass.

Greetham, H. W.
Local Manager, Water and Sewerage Co., Orlando, Fla.

Griffith, William E.
Secretary Water Commissioners, Cumberland, Md.

Groce, William R.
Superintendent, Rockland, Mass.

Hale, Richard A.
Principal Assistant Engineer, Essex Company, Lawrence, Mass.

Hall, Frank E.
Box 124, Quincy, Mass.

Hamilton, William.
89 Macdonnell avenue, Toronto, Ont.

Hammett, E. A. W.
Civil Engineer, 29 Pemberton square, Boston, Mass

Hammond, J. C., Jr.
Secretary and Treasurer, Rockville, Conn.

Hancock, Joseph C.
Superintendent. Springfield, Mass.

Haring, James S.
Civil Engineer, Lock Box 74, Nyack, Rockland, Co., N. Y.

Harrington, Geo. W.
Wakefield, Mass.

Harris, D. A.
Superintendent, New Britain, Conn.

Hart, Edward W.
General Manager Water Works, Council Bluffs, Iowa.

Hartwell, David A.
City Engineer, Fitchburg, Mass.

Haskell, John C.
Superintendent, Lynn, Mass.

Hastings, L. M.
City Engineer, Cambridge, Mass.

Hastings, V. C.
Superintendent, Concord, N. H.

Hatch, Arthur Elliot.
Mechanical Engineer, 11 Eddy street, Providence, R. I.

Hathaway, A. R.
Registrar, Springfield, Mass.

Hathaway, James H.
Registrar, New Bedford, Mass.

Hawes, Louis E.
Civil Engineer, 75 State street, Boston, Mass

Hawes, William B.
Water Commissioner, Fall River, Mass.

Hawes, William M.
Fall River, Mass.

Hawkes, William E.
President and Treasurer, Bennington, Vt.

Hayes, Ansel G.
Assistant Superintendent, Box 323, Middleboro, Mass.

Hazard, T. G., Jr.
Civil Engineer, Narragansett Pier, R. I.

Hazen, Allen.
Civil Engineer, 85 Water street, Boston, Mass.

Heald, Simpson C.
Civil Engineer, 48 Congress street, Boston, Mass.

Heermans, Harry C.
Superintendent, Corning, N. Y.

Henderson, Wilson.
Superintendent, Peterborough, Ontario, Canada.

Hering, Rudolph.
Civil and Sanitary Engineer, 277 Pearl street, New York City.

Herschel, Clemens.
Hydraulic Engineer, 2 Wall street, Room 66, New York city.

Hicks, R. S.
Secretary, Stafford Springs, Conn., Box 543.

Higgins, James H.
Supt. Meter Department, City Hall, Providence, R. I.

Hill, William R.
Chief Engineer, Syracuse, N. Y.

Hodgdon, Frank W.
Water Commissioners, Arlington, Mass.

Hodgson, John S.
Wellington, Mass.

Holden, Horace G.
Superintendent, Nashua, N. H.

Holman, M. L.
Water Commissioner, 3744 Finney avenue, St. Louis, Mo.

Hunking, Arthur W.
Care Mass. Mills, Rome, Ga.

Hunter, Henry G.
Civil Engineer, John Hancock Building, Boston, Mass.

Huntington, James A.
Registrar, Haverhill, Mass.

Hyde, Horatio N.
Superintendent, Newtonville, Mass.

Inman, A. W.
Superintendent Water Supply Co., Massillon, Ohio.

Jackson, Daniel D.
Water Analyst Boston Water Works, Newtonville, Mass.

Jackson, William.
City Engineer, City Hall, Boston, Mass.

Jenkins, Geo. S.
Water Commissioner, Lawrence, Mass.

Johnson, William S.
Assistant Engineer, State Board of Health, Room 140, State House, Boston, Mass.

Jones, A. J.
New Brunswick, N. J.

Jones, James A.
Registrar, Stoneham, Mass.

Jones, R. A.
Civil Engineer, Spokane, Washington.

Keating, E. H.
City Engineer, Toronto, Ontario, Canada.

Kempton, David B.
Water Commissioner, New Bedford, Mass.

Kenney, Joseph L.
Superintendent, Lewiston, Me.

Kent, E. W.
Civil Engineer, Woonsocket, R. I.

Kent, Willard,
Manager Water Co., Narragansett Pier, R. I.

Kieran, Patrick.
Superintendent, Fall River, Mass.

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